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(NASA-CR-170738) HIGH-SPEED BICHINING (HSM) OF SPACE SHUTTLE EXTERNAL TANK (FT) PANELS Final Report (Lockheed Missiles and Space Co.) 89 p HC A05/MF A01 CSCL 13H

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TASK A

FINAL REPORT

HIGH-SPEED MACHINING (HSM) OF SPACE SHUTTLE EXTERNAL TANK (ET) PANELS

25 FEBRUARY 1983

Prepared for

National Aeronautics & Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812



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Contract:

NAS8-34508

FOREWARD

Lockheed Missiles and Space Company, Inc. is pleased to submit this Task A final report to the National Aeronautics and Space Administration, Marshall Space Flight Center in accordance with Contract Number NAS8-34508. The program, summarized herein, covers Task A of the contract as it has been adjusted since originally awarded. The changes made transferred the paragraph "Identify Potential High-Speed Milling Procedures" from Task A to Task B where it is entitled "High-Speed Milling Procedures and Times," and descoped the Task A paragraphs entitled "Analysis of Present Manufacturing Methods" and "Time and Motion Study."

This submission is not intended to duplicate the Task B report and documents primarily the findings of the Task A activities.

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Section 1 INTRODUCTION

The External Fuel Tank (ET) of the Space Shuttle (Figures 1-1 and 1-2) is not recovered after launch and a new one must be provided for each launch. Currently, the external "skin" panels of the tank are produced by machining from solid wrought 2219-T87 aluminum plate stock approximately 1-3/4 inch thick. The reduction of costs in producing External Fuel Tank panels is obviously of particular significance.

This study, which is divided into Tasks A and B, was initiated to investigate the feasibility of increasing production rates and decreasing costs of the panels through the application of high-speed machining (HSM) techniques.

1-1 TASK A OBJECTIVES

Task A (the subject of this report) was designed to study potential production rates and project cost savings achieved by converting the current conventional machining process in manufacturing Shuttle External Tank panels to HSM techniques. Savings were to be projected from the comparison of current production rates with HSM rates and with rates attainable on new conventional machines. The HSM estimates were also to be based on rates attainable by retrofitting existing conventional equipment with high-speed spindle motors and rates attainable using new state-of-the-art machines designed and built for HSM.

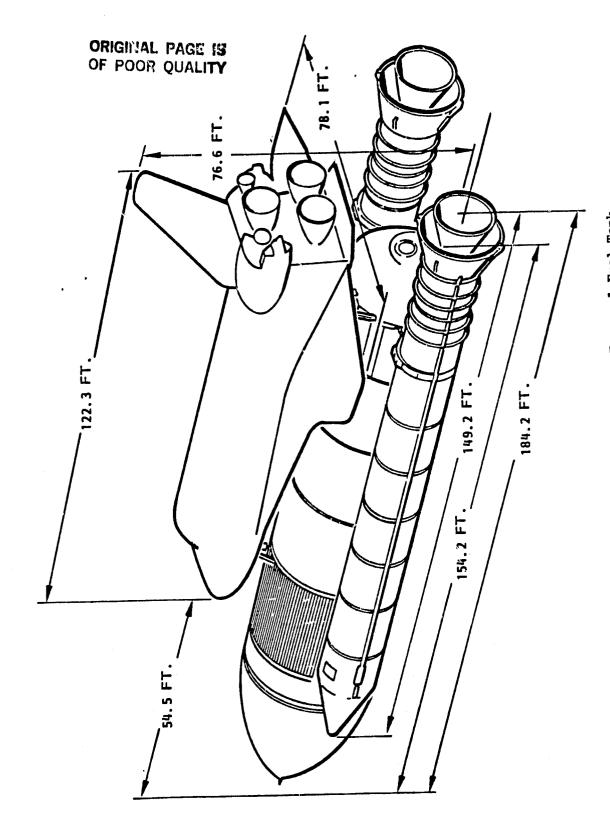


Figure 1-1. Space Shuttle Attached to External Fuel Tank

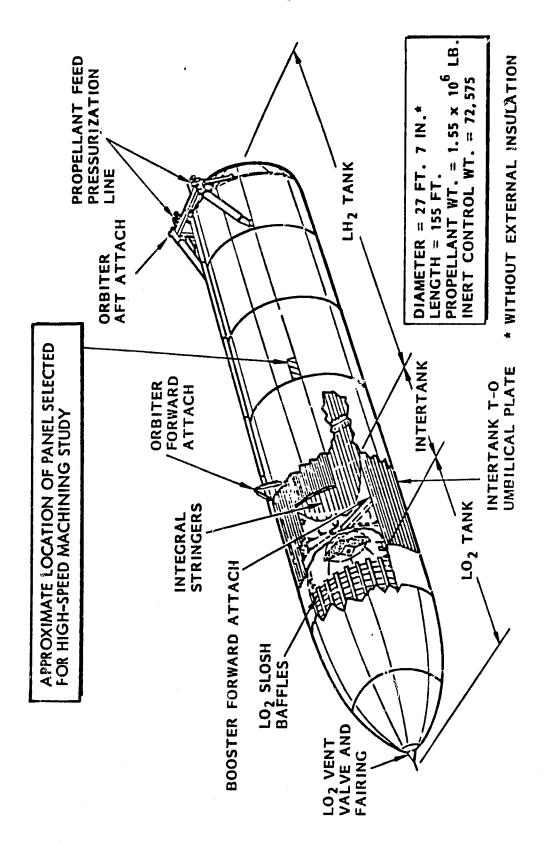


Figure 1-2. Detail of Space Shuttle External Fuel Tank

Section 2 SUMMARY - TASK A

Lockheed Missiles and Space Company, Inc., contracted with the Marshall Space Flight Center at Huntsville, Alabama to study the feasibility of transferring the high-speed machining (HSM) techniques developed at LMSC for milling aluminum missile parts to the machining of Space Shuttle External Fuel Tank Panels.

The goals of Task A were to:

- a. Investigate current machining techniques.
- b. Using a production rate of 64 panels per month for 84 months as a basis, compare current production rates and costs to projections based on retrofitting present equipment to HSM.
- c. Compare current production rates and costs to projections based on replacing present equipment with new HSM equipment.
- d. Compare current production rates and costs to projections based on replacing present equipment with new conventional equipment.
- e. Perform an economic trade-off analysis comparing various machine options.

A gantry type milling machine presently being used to machine Shuttle Fuel Tank panels was utilized as a basis for comparison in this study. Information was gathered from several machine tool builders active in HSM, from HSM spindle manufacturers, and from machine tool rebuilders.

Projected machining times and labor and machine investment costs were determined for 41 specific machine tool configurations.

Findings of the study indicated that significant improvements in machining production rates and cost over the present machine used as a basis for comparison can be realized with new currently available state-of-the-art HSM equipment. Using proven HSM equipment, production rates could be increased from 3.9 panels per month currently to 73.5 panels per month. This increase in production level could be accomplished using a one panel wide, two panel long gantry-type mill with two 75 hp, 9,000 rpm spindles. The use of advanced HSM

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equipment (not fully proven but at a high confidence level) with two 100 hp 12,000 rpm spindles would increase production rates to 86.6 panels per month. Projected rates for two panel wide machines are even higher, but the costs are also higher. Projected rates for unproven HSM 150 hp, 24,000 rpm spindles for both one and two panel width machines would push production rates still higher if appropriate cutters were available.

By retrofitting two 100 hp, 12,000 rpm HSM spindles on the present gantry-type mill, production rates could be increased from 3.9 panels to an estimated 43.3 panels per month. Two machines thus converted would be needed to achieve the 64 panel per month production requirement.

New conventional machines could be used to increase production rates from 3.9 currently to 87.6 panels per month. This level could be accomplished with a two panel wide, two panel long gratry-type mill and four 150 hp, 3,600 rpm spindles.

The HSM panel machining times determined from the actual 4 foot by 8 foot panel section machining performed in Task B correlated very closely with the machining times projected in Task A. As an example, 6.0 hours was projected in Task B to machine a full-size panel using a single 75 hp, 9,000 rpm spindle machine. Using the detailed procedures determined in Task A, 5.9 hours was estimated for the same situation.

Areas limiting production levels and that require further development are cutters, chip removal, and panel loading and unloading.

Section 3 TASK A EFFORT

The major efforts involved in Task A are as follows:

- 1) Survey present facilities.
- 2) Gather data on conventional machine and determine cost of conversion to HSM and projected schedule.
- 3) Obtain conventional machining operation steps and times.
- 4) Assess new machines.
- 5) Determine cost and delivery schedule for new conventional machine(s).
- 6) Determine cost and delivery schedule for HSM machines.
- 7) Determine barrel panel machining times for new conventional and new HSM machines.
- 8) Perform Economic Trade-Off Analysis comparing various machine options.
- 9) Produce HSM implementation plan for each option.
- 10) Write a final report.

4 TASK A TECHNICAL APPROACH

Following is a summarized description of the detailed steps involved in the Task A study.

4-1 SURVEY OF PRESENT FACILITIES

A visit was made to an existing machine vendor
where some of the Shuttle External Tank panels are currently machined.
The panel machining operation taking place on a gantrytype mill was briefly observed. Following is a compilation of the information gathered regarding the machine and the various machining parameters involved in milling the panel.

Machine: Gantry type mill (in service only 6 months since major rebuild)
(Navy owned)

144" x 480" table

X axis = 480" (40")

 $\frac{1}{3}$ axis = 146" (12')

Z = 12'' (1')

Wilson 20 hp, 1800/3600 rpm, 440v, 3 phase spindle motor (only 13 hp available due to electrical overloading condition)

Axes motions at 240 ipm rapid and 200 ipm programmable (originally) but currently capable of 200 ipm rapid and 150 ipm programmable All axis drives (originally hydraulic) have been replaced with dc electric drives

The gantry drive motors were:

Inland Motors
Industrial Drive Division
Radford, Virginia
Model TTF2-5306-201-B
Ser. 81D82-50
2400 rpm max.
Cont (stall) 11v, 146 amp, 60 lb-ft.
Peak (stall) 14v, 200 amp, 82 lb-ft.

Controls: Allen Bradley Model 7320 CNC

Cutter sizes and maximum cuts:

- 1) Roughing cutter: 5-1/4" dia, 4-flute, at 3600 rpm and 12 ipm (average of .300" deep (.475 max) at full width)
- 2) Finishing cutter for bottom of pocker: same as roughing cutter but only .100" deep
- 3) T-rib cutter: 4" dia, 6-flute, .625" or .725" flute height (full width and full depth (.725) used at 3600 rpm and 40 ipm at top of T). Maximum radial depth of cut = .575".
- 4) Profiling cutter for sides to T: 2-1/2" dia, at 3600 rpm and 40 ipm. (Assumed to cut 3/8" radii at bottom of T, etc.)

This information was gathered in light of possibly retrofitting the machine to HSM capabilities in addition to gaining a better understanding of how the panels are presently being machined. In regard to a possible retrofit, the new Allen Bradley Model 7320 CNC controls and the fact that the machine had been recently rebuilt were felt to be definite positive points. A point which was felt to be negative was that the maximum programmable gantry feed was rated at 200 ipm but presently the machine was limited to operation at a maximum of 150 ipm. A second negative point was that the electrical power supply to the machine appeared inadequate and would need to be remedied.

The small (20 hp) spindle motor installed on a machine originally designed for a considerably larger motor(s) indicated that problems with machine vibration may have been experienced with the larger motor(s). If so, potential problems with retrofitting to high speed spindles could be expected.

4-2 COLLECTION OF DATA FROM MACHINE TOOL BUILDERS AND REBUILDERS
To obtain pertinent information regarding state-of-the-art HSM machines and related equipment, machine tool and HSM spindle builders were contacted who were known to be actively involved in the manufacture of HSM equipment of the size and type being studied.

Information relative to new machines capable of machining the Shuttle External Tank panels at conventional machining rates was also obtained. In all instances, details were solicited regarding machine specifications, cost, and delivery schedule.

The general approach taken was to telephone the machine tool builder assuring contact with the appropriate person and then follow up by letter with the necessary details. In several instances, personal meetings were held.

One general large machine tool rebuilder was contacted regarding the possible retrofitting of the present machine to HSM capabilities. Additional retrofit information was obtained from the original manufacturer of the machine and the Bryant Grinder Division of the Excello Corporation (builder of HSM spindle motors.

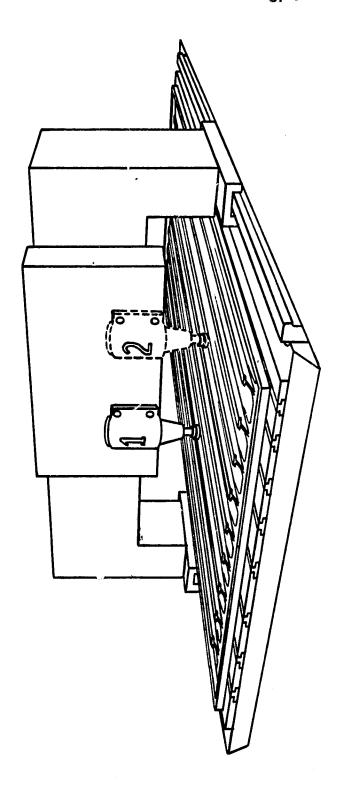
4-3 SELECTION OF GENERAL MACHINE TOOL CONFIGURATIONS

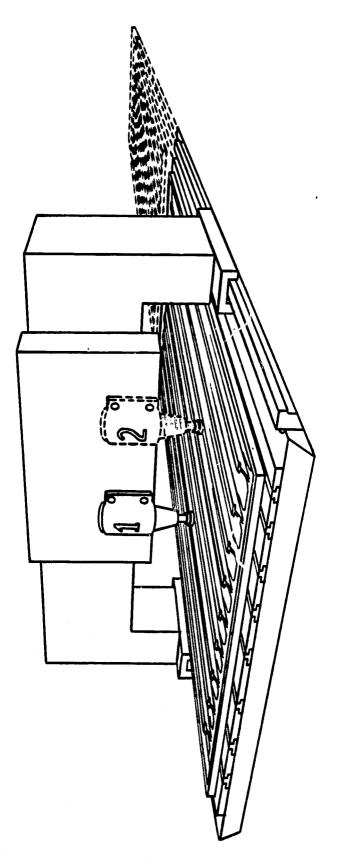
The most common general approach to machining large panels such as those used for the Shuttle External Fuel Tank (11' x 20') is to mount them on a stationary horizontal table and to mount vertical (or a combination of vertical and horizontal) spindles on a moveable gantry. Considerably less moveable mass is involved in moving a gantry over the part than in moving an entire table capable of properly supporting such large parts, especially if the table is large enough to mount more than one panel at a time.

A moveable gantry type machine with one or two spindles (Figure 4-1) machining a one panel width (11') was the first general configuration considered in the study. The machine presently being used to machine Shuttle Tank panels fits into this category.

The second general configuration of machine tool included in the study was the same as the first except with a two panel length table (Figure 4-2). The lengthened table would allow loading and unloading to take place without interrupting the machining process.

A third general configuration considered was a gantry type machine capable of machining a two panel width (22'plus) using two or four spindles (Figure 4-3). This machine configuration was considered with both single and double length tables.





Basic Gantry-Type Machine With Lengthened Table to Allow Loading and Unloading of Second Part Figure 4-2.

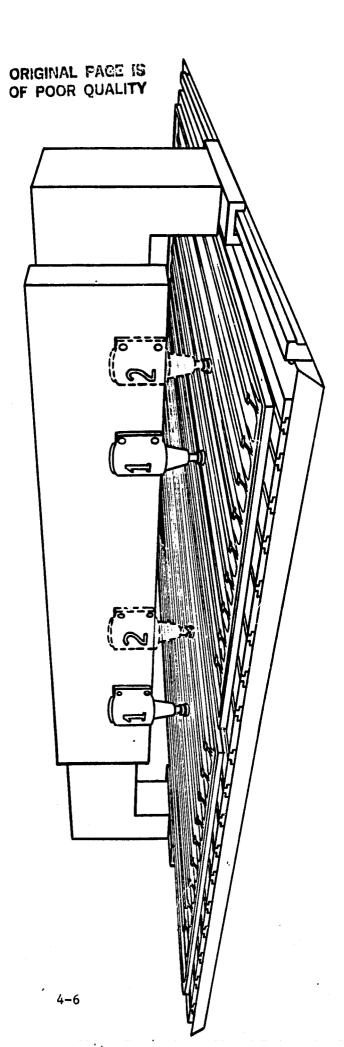


Figure 4-3. Two Panel Wide Gantry-Type Machine With Two or Four Spindles

An additional variation of the gantry type machines included in the study was a vertical spindle(s) for finish machining but separate horizontal spindle(s) for rough machining.

The fourth general configuration considered (Figures 4-4 and 4-5) involves machining panels that are mounted vertically. Either one, two, or four horizontal spindles would be used to machine one or two panels at a time. A decided advantage of mounting the panels vertically would be the relative ease of chip handling through use of a conveyor at the base of the panel.

Descriptions of the specific machine tool configurations considered in the study are included in Section 4-5.3.

4-4 DETERMINATION OF CUTTERS TO BE USED IN STUDY

The full potential of high-speed machining is still being developed. Spindles with higher rpm and horsepower are being introduced on the market. Along with these advances, however, is a definite need for more advanced cutter designs and cutter materials.

The most appropriate combinations of cutters, feeds, speeds, and depths of cut to machine the tank panels were based on the following considerations:

- a) Lockheed's background in HSM
- b) The cutters utilized and demonstrated in Task B of this contract
- c) The cutters presently in use at the existing vendor for machining tank panels.
- d) Information from sources including cutter manufacturers and machine tool builders

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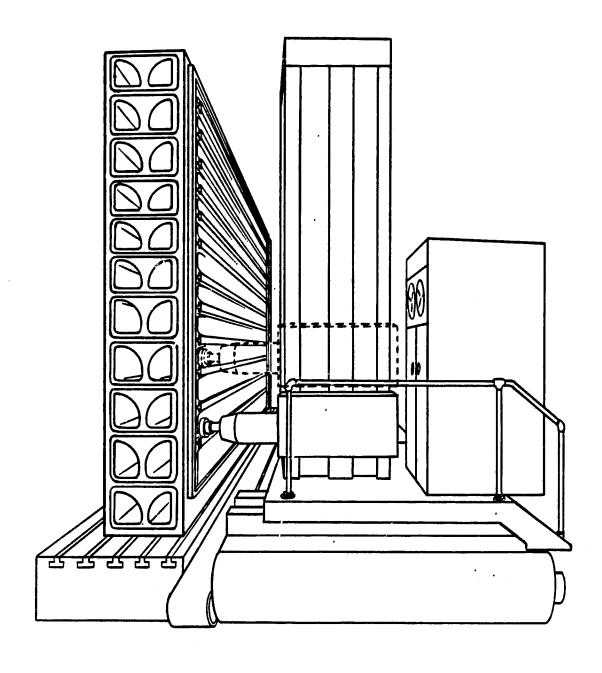


Figure 4-4. Moveable Column Machine With One or Two Spindles

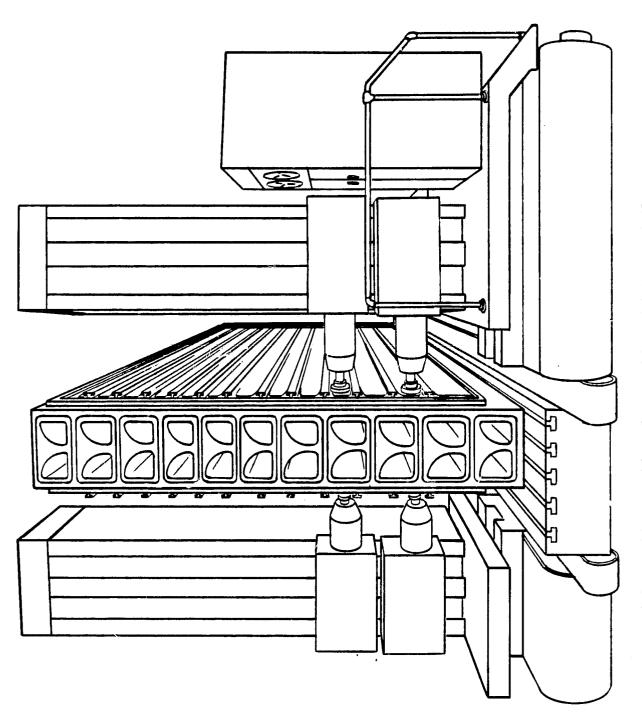


Figure 4-5. Double Moveable Column Machine With Four Spindles

angles and other details would be made to correlate with the higher cutting speeds projected in the study. However, for roughing and finishing the pockets between the T-ribs of the panels, calculations for different cutter diameters were examined (See Section 5 and Appendixes A and B for details).

Substitutions for the 5-1/4 inch diameter-four toothed cutter presently in use for both roughing and finishing included 1) a 14 inch diameter by 2.8 inch wide roughing cutter to be used with the horizontal spindle motors; 2) a 2 inch diameter, three-flute end mill for roughing, and 3) a 9 inch diameter cutter for roughing and finishing. The 9 inch cutter would have the advantage of finishing the entire width of the pocket in one pass thus eliminating tool marks and potential mismatch in the bottom of the pocket.

Except for the very highest theoretical cutting speeds, the cutters and accompanying parameters chosen were considered reasonable, but not necessarily optimum. For example, more teeth for a given diameter might improve machining time if ample chip clearance for the higher cutting speeds could still be provided.

Safety, especially at the higher cutting speeds, is an obvious concern regarding any cutter development and usage. Brazed carbide insert-type cutters were assumed for instances where insertable teeth might not be safe.

4-5 CALCULATIONS OF MACHINING TIMES AND PRODUCTION CAPACITIES
A required production rate of 64 Shuttle External Tank panels per month for
84 months starting in 1985 was specified by NASA as a basis for this study.
The specific objectives of the study were to determine potential production
rates and cost savings from converting to HSM techniques from the conventional
machining process presently employed in milling the panels from 1.75 inch
thick aluminum plate.

A consideration of all aspects of the panel production process was not within the scope of this study. The results shown are intended for comparison with only the appropriate portions of the total process. Estimated machining rates for these portions of the present process are included. Examples of machining operations not included in the comparisons are the preparation of the outside or bottom of the panels and the drilling and tapping of holes. Both of these operations can be considered to take place on other equipment and are not considered necessary to the study.

The following sub-sections describe the considerations involved in projecting machining times and production capacities for the general machine tool configurations described previously in Section 4-3.

4-5.1 Selection of Typical Panel

The panel specified for this study by the NASA Marshall Space Flight Center and their prime contractor for the Shuttle Tank, Martin Marietta, was described on Martin Marietta Drawing Number 8094200997. This panel is comparable to the one from which the demonstration sample was machined as part of Task B. It is 11 feet wide by 20 feet long and is milled from 1.75 inch thick 2219-T87 aluminum plate. Twelve longitudinal T-shaped reinforcing ribs are spaced 10.8 inches apart (Figure 4-6). An estimated 91 percent of the metal is removed.

The panel is machined from a premachined blank from which over half of the metal has already been removed. However, for the purposes of this study, all machining times including the references, are based on starting from a 1.75 inch thick solid plate.

4-5.2 Cutting Speed Limitations

As a basis for the study, projected machining rates and panel production capacities were calculated without the restraints of cutting speed limitations (expressed in surface feet per minute-sfpm). Essentially, the assumption was made that cutters were available (or would soon become available) that would allow the utilization of the full capacities of the machine tools. The tables shown in this report are based upon this assumption.

In several instances, the cutting speeds calculated were substantially above current demonstrated levels. Upon investigation, a smaller diameter cutter at the same rpm but deeper axial depth of cut was found to remove a similar amount of metal at a lower cutting speed (in currently proven range). For example, the 2 inch, 3-flute end mill used in the 150 hp, 24,000 rpm spindle machines as a roughing cutter with a .508 inch depth of cut provided similar metal removal rates as the 9 inch cutter with a .066 inch depth of cut on the same machines (Table A-1, Appendix A).

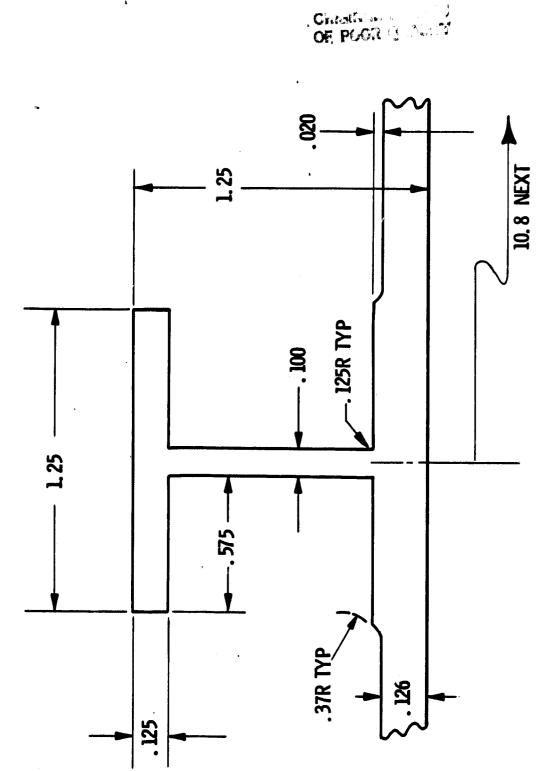


Figure 4-6. Section View of T-Rib Reinforcement of Fuel Tank Panel

The potential for obtaining cutters capable of the maximum cutting speed indicated in this study (56,549 sfpm) was pursued further. A spokesman for a major cutter manufacturer involved directly in cutter development for HSM stated that a cutter capable of machining aluminum at 56,000 sfpm is felt to be feasible. Cutting speeds in aluminum at up to at least 28,000 sfpm have already been demonstrated successfully.

4-5.3 Specific Machine Tool Configurations Used in Study

Projected panel machining times and monthly production rates were determined for the following specific gantry type machine tool configurations. (The columns of the tables showing the results are arranged in this order throughout the report):

- a) Present conventional gantry type mill with one 20 hp, 3,600 rpm spindle, and 200 ipm gantry feed (Figure 4-1).
- b) Present conventional gantry type mill <u>retrofitted</u> with new HSM 100 hp, 2,600 rpm conventional spindle(s) (1 or 2) and 200 ipm gantry feed (Figure 4-1).
- c) <u>Present conventional</u> gantry type mill <u>retrofitted</u> with new HSM 100 hp, 12,000 rpm spindle(s) (1 or 2) and 200 ipm gantry feed (Figure 4-1).
- d) New Conventional gantry type mill with horizontal 100 hp, 3,600 rpm and vertical 150 hp, 3,600 rpm spindle combination(s) (2, 4 or 8 spindles) and 300 ipm gantry feed for one panel width and 200 ipm gantry feed for two panel widths (This configuration is similar to Figures 4-1 and 4-3 but with both vertical and horizontal spindles).
- e) New conventional gantry type mill with vertical 150 hp, 3,600 rpm spindle (s) (1, 2 or 4) and 300 ipm gantry feed for one panel width and 200 ipm gantry feed for two panel width (Figures 4-1 and 4-3).
- f) New HSM gantry type mill with vertical 75 hp, 9,000 rpm spindle(s) (1, 2, or 4) and 600 ipm gantry feed for one panel width and 200 ipm for two panel widths (Figures 4-1 and 4-3).
- g) New HSM gantry type mill with vertical 100 hp, 12,000 rpm spindle(s) (1, 2, or 4) and 400 ipm gantry feed for one panel width and 200 ipm for two panel widths (Figures 4-1 and 403).
- h) New HSM gantry type mill with vertical 150 hp, 24,000 rpm spindle(s) (1, 2 or 4) and 1,000 ipm gantry feed for both one and two panel widths (Figures 4-1 and 403).
- 1) New HSM gantry type mill (same as 8) except calculations are made using different roughing cutter.

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Machining times and production rates were also calculated for configurations d) thru h) with two panel length tables. The lengthened tables were to provide loading and unloading capability without interrupting the machining process.

The outputs from the vertical panel machines (Figures 4-4 and 4-5) are expected to be comparable to the outputs attainable on the horizontal panel machines. However, development of the vertical panel machines has not progressed as far as for the horizontal machines and a column feed rate of 200 ipm was the apparent maximum.

4-5.4 Machining Parameters (Appendixes A and B) Cutters

The study was based primarily on cutter sizes used for the present operation. where applicable (Section 4-1 and 4-4). The cutters used for roughing and finishing the pockets between the T-ribs were changed from the 5-1/4 inch diameter to 9 inches in most instances. For the combination horizontal and vertical spindle machines, a 14 inch diameter by 2.7 inch wide staggered tooth cutter with 8 teeth was used for roughing. This cutter was reportedly being used effectively on similar panels being machined at other facilities. A 9 inch diameter cutter in the vertical spindle was used for the finishing.

Calculations were also made for roughing and finishing the pockets using a 5-1/4 inch cutter (as now used) on all of the machine configurations. The results are not shown in the report since in all instances the time was greater than when using the 9 inch diameter cutter.

Spindle Speeds

The maximum rpm available was used unless otherwise noted.

Horsepower Required

The metal removal rates are based on a full 100 percent of the rated horse-power of the spindle motors. The amount shown was calculated by dividing the cu in./min by a cutting efficiency factor of 4.0 cu in./min/hp (demonstrated in Task B and in other instances of HSM).

Chin Load

HSM research has defined optimum chip loads (chip per tooth) for milling aluminum¹. Chip loads of .007 inches for roughing and .003 inches for finishing were taken from these recommended ranges and maintained as constants throughout the study. Exceptions were the present operations and a few other instances as noted where machine capabilities were limiting. Number of Layers

The number of layers in which the metal in the pockets between the ribs was rough machined was determined by computing the maximum cross-sectional area of metal removeable based upon a cutting efficiency factor of 4.0 cu in/min/hp and the available horsepower. The maximum axial depth of cut equivalent for the full diameter (radial depth of cut) of the cutter was then calculated. This maximum depth per pass was then divided into the total roughing depth of 1.525 inches (1.75"-.100" finish cut - .125" panel thickness). The figure was adjusted to the next larger whole number and the 1.525 inch roughing depth was divided into equal depth layers each of which was considered to be the depth of cut (axial).

Number of Passes per Pocket

The number of passes per pocket was determined by multiplying the number of layers by the number of passes per layer.

Depth of Cut (Axial)

(See Number of Layers)

Depth of Cut (Radial)

The full diameter of the cutter was used as the radial depth of cut for the vertical spindles. For the horizontal spindles the radial depth was calculated depending on the number of passes required to achieve the depth of the pocket.

Table (Gantry) Feed Used

This value was calculated in each instance based on constant chip load, rpm, and number of teeth in the cutter. The calculated value was used unless the maximum capability of the machine was limiting. In such instances the exception was noted.

Cu In./Min - Metal Removal Rate

The metal removal rate value in cubic inches per minute was based on the maximum rate used and the full width of the cutter.

¹J. McGee et al, "Manufacturing Methods for High Speed Machining of Aluminum," Final Technical Report, Vought Corporation contract No. DAAK-40-76-C-1329; submitted to U. S. Army Missile Research and Development Command, February 1, 1978.

Cutting Speed

This value was computed as the peripheral speed of the cutter at the given rpm expressed in surface feet per minute (sfpm).

4-5.5 Chip Cutting Time for Each Machining Operation
Chip cutting time was considered to be only that time during which the
revolving cutter is actually engaging the workpiece. Detailed calculations
for each of the separate machining operations and for each machine configuration considered are shown in Appendixes A and B. The cutter paths used are
considered reasonable but not necessarily optimum. Optimization of the cutters
and other parameters should yield even shorter cutting times. A summary of
these individual machining operation times and a composite total is provided
in Table 4-1.

The data (Table 4-1) show that as rpm is increased the total chip cutting time is decreased. Theoretically, if a table feed of 1,344 ipm had been available for the 150 hp, 24,000 rpm spindle machine, an additional .359 hours (21.54 minutes) per panel would have been saved.

The values shown in Table 4-1 (and Appendixes A and B) are based upon one spindle operation. These one spindle values are expanded to the two and four spindle levels by dividing the one spindle chip cutting time by two and by four, respectively.

4-5.6 Total Machining Time

Machining time was computed to be the sum of chip cutting time plus between pass cutter positioning time. The time allowed for positioning was adjusted according to the maximum gantry feed available for the particular machine tool configuration. Tool changes, operator break, and down times were not included.

Table 4-2 shows the estimated machining time per spindle for one, two, and four spindle machines. This separation was required because the gantry feed of the four spindle machines is slower.

Summary of Estimated Chip Cutting Time (Hours), Per Panel (Based on One Spindle) Table 4-1.

}-wa			finite all residents and a	عربنيو د الأداك ا	OF	RIGINAL POOR		ige Iali	[9 r rY ,				LMSC 1	0-059359
		HINING	Verrical	Spindle 150 hp 24000 rpm	2" Rough 9" Finish		7087	967°L	.084	169	.346	070	.037	2.708
NS		H SPEED MACHINING	Verrical	Spindle 150 hp 24000 rpm	9" Rough & Finish		.084	1,220**	-084	.691	.346	070	.037	2.502**
MACHINE TOOL CONFIGURATIONS	NEW	HIGH	Vertical	Spindle .100 hp	9" Rough & Finish		.167	1.716	.181	1.382	.691	0%0	.073	4.250
HINE TOOL C			Vertical	Spindle 75 hp 9030 rpm	9" Rough & Finish		.225	2.368	.243	1.728	.864	070.	.092	5.560
NAC		CONVENTIONAL	· · Vertical	Spindle 150 hp 3600 rpm	9" Rough & Finish		.547	1.295	.593	4.493	2.246	.040	.238	9.452
		CONVE	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish		.547	2.766	.593	4.493	2.246	.040	.238	10.923
	FIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish		.239*	1.813*	.259*	1.382	.691	070	.073	4.497*
	RETROFIT	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish		.547	1.813	.593	4.493	2.246	.040	.238	9.970
		PRESENT	Existing	20 hp 3600 rpm	Cutters→ 5½" Rough & Finish		4.032	32.256	8.064	4.838	2.419	.040	.256	51.905
					Cutters+	MACHINING OPERATIONS	s I Jo dol 1111177	Rough Mill Pockets	Finish Mill Pockets (.100")	Mill T-Ribs	Mill Edge of T's and Radii	Mill Taper on T Ends	Mill Periphery	Total Chip Cutting Time

*Limited by 200 ipm table travel.

Table 4-2. Summary of Estimated Machining Time Per Panel (Chip Cutting Time Plus Cutter Positioning Time)

								Or .		,, &-	MLIET						
		(HSM)	Vertical	Spindle 150 hp 24000 rpm	2" Rough 9" Finish			.0005	.0005	303	المراجع والمراجع	.152	.152		2.860	2.860	
NS		MACHINING (1	Vertical	Spindle 150 hp 24000 rpm	9" Rough & Finish			.0005	.0005	416		.208	.208	•	2.710	2.710	
NACHINE TOOL CONFIGURATIONS	NEW	Α	Vertical	Spindle 100 hp 12000 rpm	9" Rough & Finish	4.250 (4.497 for		.00125	.0025	404 (209)		.505	.523		4.755	5.020	
HINE TOOL C			Vertical	Spindle 75 hp 9000 rpm	9" Rough & Finish	5.560		.00083	.0025	417		.346	1.043		5.906	6.603	
MAC				Spindle 150 hp 3600 rpm	9" Rough & Finish	9.452		.00167	.0025	183		.306	.458		9.758	9.910	
			Horiz. for Rough Vert. for	finish 100&150 hp 3600 rpm	14" Rough 9" Finish	10.923		.00167	.0025	266		777	.665	·	11.367	11.588	
		ſ		E													
	RETROFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish	4.497		.0025	l .	209		.523	ı		5.020	i	
	RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish	9.970		.0025	ł	209		.523	ļ		10,493	ı	
		PRESENT	Existing	20 hp 3600 rpm	5½" Rougl & Finish	51.905		.0025	ı	225		.563	ì		52.468	l	
					Cutters→ PARAMETERS	Total Chip Cutting Time (Hours)	Positioning Time	ΔA One or Two SpindleMachine (Hours)Four Spindle	Machine (Hours)	# of Passes	Total Cutter Positioning Time	-One or Two Spindle Machine (Hours) -Four Smindle	Machine (Hours)	Total Machining Time (Hours)	-One or Two Spindle Machine (Hours) -Four Spindle	Machine (Hours)	

4-5.7 Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity Total floor-to-floor time was determined to be the machining time plus operator break, fatigue, and personal time plus panel loading and unloading time. The operator break, fatigue, and personal time was estimated at 20 percent of machining time. Panel loading and unloading time was included at the reported present rate of 3.0 hours for the one panel width machines and an estimated 4.5 hours (2.25 hours per panel) for the two panel width machines. As the loading and unloading times were considered to be different for one and two panel width machines and also for one and two panel length machines, separate tables (C-1 through C-6) are shown in Appendix C for each of these categories. The monthly panel machining capacity was computed by dividing the total floor-to-floor time into the 325.5 hours per month total production time available on a two shift basis. This 325.5 hours per month was determined as follows:

Day shift: 21 days x 8 hours/day = 168 hours

Swing shift: 21 days x 7.5 hours/day = 157.5 hours

Total for two shifts = 325.5 hours

Operator break, fatigue, and personal time have already been included in the floor-to-floor time. However, maintenance and other down times have not been allowed for.

A summary of total floor-to-floor machining time and monthly panel machining capacity is given in Tables 4-3 and 4-4.

It is noteable that in all instances the estimated monthly panel capacity increases as rpm is increased unless the capacity is limited by the load and unload time. It is also of interest that the estimated monthly panel capacity increases for each number of spindles when the table is lengthened to allow loading and unloading during machining.

4-6 ECONOMIC TRADE-OFF ANALYSIS

An economic trade-off analysis is a very important aspect of the High-Speed Machining of Space Shuttle External Tank Panels study. Even though the HSM process might be shown to produce panels faster, if the cost for producing the panels by this means is too high the change could not be justified. The approach taken to determine the estimated costs involved in machining panels using each of the 41 machine tool configurations included in the study was to assess both the machine investment cost and the machining time or labor figure. Some additional manufacturing costs, such as panel premachining which were considered to be essentially the same for each of the configurations, were not included in

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One Panel Length Machine Summary of Total Floor-to-Floor Machining Time, Per Panel, and Monthly Panel Machining Capacity Table 4-3.

MS(U L)-0:	935	9					OF P	001	ROS	ALTY			
				Vertical	Spindle 150 hp 24000 rpm	2" Rough 9" Finish		6.432	40.5 50.6		4.716	55.2 69.0		3.108	83.8 104.7
	4S		ر (HSM)	Vertical	Spindle 150 hp 2400G rpm	9" Rough & Finish		6.252	41.7 52.1		4.626	56.3 70.4		3.064	85.0 106.2
	CAFIGURATION	NEU	SPEED MACHINING	Vertical	Spindle 100 hp 12000 rpm	9" Rough & Finish		8.706	29.9 37.4		5.854	44.5		3.743	69.6 87.0
MACHINE TOOL CONFIGURATIONS	IINE TOOL CO		HIGH SPE	Vertical	Spindle 75 hp 9000 rpm	9" Rough & Finish		10.087	25.8 32.3		6.544	39.8 49.7		4.196	62.1 77.6
	MACI		TONAI.	Vertical	Spindle 150 hp 3600 rpm	9" Rough & Finish		14.710	17.7		8.855	29.4 36.8		5.224	49.8
			CONVENTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough ?" Finish		16.640	15.6 19.6		9.821	26.5 33.1		5.726	45.5
		DFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Fic≗sh		9.024	28.9 36.1		6.012	43.4 54.1	- Tallian ary is	ı	1 1
		RETROFIT	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish		15.592	16.7 19.5		9.296	28.0 35.0		1	i 1
	ı		PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish		65.962	3.9		ı	1 1		1	1 1
					,	Cutters→ PARAMETERS	One Spindle	Total Floor-to-Floor Time (Hours)	Monthly Capacity 2 shifts/80% Cap. 2 shifts/100% cap.	Two Spindle	Total Floor-to-Floor Time (Hours)	Monthly Capacity 2 shifts/80% Eff. 2 shifts/100% Eff.	Four Spindle	Total Floor-to-Floor	Monthly Capacity 2 shifts/80% Eff. 2 shifts/100% Eff.

Summary of Total Floor-to-Floor Machining Time, Per Panel, and Monthly Panel Machining Capacity Table 4-4.

Two Panel Length Machine

							Oktal	NAL PAG	ee is	LMSC D-059359								
		(HSM)	Vortical	Spindle	150 hp 24000 rpm	2" Rough 9" Finish	3.432	75.9 94.8	3.000 (1.716)	86.8 (151.7)	108.5	2.250 (.858)	115.7	(303.3) 144.7 (379.4)				
SI		MACHINING (H	Torefool	Spindle	150 hp 24000 rpm	9" Rough & Finish	3.252	80.1 100.1	3.000 (1.626)	86.6 (160.1)	108.5 (200.2)	2.250 • (.814)	115.7	(319.9) 144.7 (399.9)				
TOOL CONFIGURATIONS	NEW	HIGH SPEED N	Looidadh	Spindle	100 hp 12000 rpm	9" Rough & Finish	5.706	45.6 57.0	3.000 (2.854)	86.8 (91.2)	108.5 (114.1)	, 2.250 (1.493)	115.7	(1/4.4) 144.7 (218.0)				
NACHINE TOOL CO			[20,400]	Spindle	75 hp 9000 rpm	9" Rough & Finish	7.087	36.7 45.9	3.544 (2.854)	73.5	91.8	2.250 (1.946)	115.7	(133.8) 144.7 (167.3)				
NACI		FIONAL	Vortical	Spindle	150 hp 3600 rpm	9" Rough & Finish	11.710	22.2 27.8	5.855	44.5	55.6	2.974	87.6	109.4				
		CONVENTIONAL	Horiz. for Rough	Finish	100&150 hp 3600 rpm	14" Rough 9" Finish	13.640	19.1 23.9	6.821	38.2	47.7	3.476	74.9	93.6				
	TI	HSM		Existing	100 hp 12000 rpm	9" Rough & Finish	ı	1 1	l	ı	1	ı	ı	1				
	RETROFIT	CONV.		Existing	100 hp 3600 rpm	9" Rough & Finish	-	1 1	ı	l	ı	1		l				
		PRESENT		Existing	20 hp 3600 rpm	5½" Rough & Finish	65.962	3.9	ı	ı	ļ	ı	ı	ı				
		(XXX) value if not	Limited by equipment			Cutters→ PARAMETERS	One Spindle Total Floor-to-Floor Time (Hours)	Monthly Capacity 2 shifts/80% Eff. 2 shifts/100% Eff.	Two Spindle Total Floor-to-Floor Time (Hours)	Monthly Capacity 2 shifts/80% Eff.	2 shifts/100% Eff.	Four Spindles Total Floor-to-Floor Time (Hours)	Monthly Capacity 2 shifts/80% Eff.	2 shifts/100% Eff.				

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the comparison study.

The production requirements were specified to be 64 panels per month for 84 months (5,376 panels) starting in 1985. The costs were computed both per panel and per the total 5,376 panels.

4-6.1 Labor Costs Per Panel and Per 5,376 Panels

The labor cost per panel for each of the 41 configurations was determined by multiplying the total floor-to-floor machining time per panel by a constant labor rate. An appropriate labor charge for the type of work and equipment involved was estimated at \$60 per hour. These labor costs are shown in Table D-1 and D-2 of Appendix D. Also shown are the labor costs projected for the total 5,376 panels if machined by each of the configurations.

4-6.2 Machine Investment Costs Per Panel and Per 5,376 Panels
The costs of the machines were estimated by various machine tool builders. A
degree of interpolation was involved in costing certain specific machine tool
configurations. In the case of the retrofit machines, no value for the present
machine was allowed; only additional investment costs were figured. The
primary costs for the retrofits were for the HSM spindle motor systems.

The cost of the vacuum chuck system was, in some instances, included in the cost of the machine. The estimates for installation and debug and test were determined from inputs from the machine tool builders and from Lockheed personnel experienced in the area (Tables E-1 through E-6, Appendix E).

4-6.3 Combined Machine Investment Plus Labor Costs Per Panel and Per 5,376 Panels The machine investment costs and the labor costs for the various machine tool configurations are combined in Tables F-1 through F-6 of Appendix F. Both costs per panel and per the total of 5,376 panels are shown. Summary comparisons of these combined costs per panel are given in Table 4-5 and total costs for all 5,376 panels are given in Table 4-6.

Of interest is the indication that, for the new machines, the combined cost per panel goes down as the rpm of the spindle motors goes up.

Summary of Combined Total Machine Investment Plus Labor Cost (\$) Per Panel Table 4-5.

					ORIGINAL OF POOR	PAGE 13		LMSC D	-059359	
		IINING	Vertical Spindle 150 hp 24000 rpm	2" Rough 9" Finish	662	512	909	535 (456)	699	676 (592)
S		H SPEED MACHINING	Vertical Spindle 150 hp 24000 rpm	9" Rough & Finish	651	501	879	533 (451.)	299	676 (590)
MACHINE TOOL CONFIGURATIONS	NEW	HIGH	Vertical Spindle 100 hp 12000 rpm	9" Rough & Finish	859	741	753	645 (636)	783	806 (761)
IINE TOOL CO			Vertical Spindle 75 hp	9" Rough & Finish	923	1,972	739	622	791	787 (769)
MACI		IONAL	Vertical Spindle 150 hp 3600 rpm	9" Rough & Finish	1,266	1,167	942	844	852	830
		CONVENTIONAL	Horiz. for Rough Vert. for Finish 100£150 hp 3600 rpm	14" Rough 9" Finish	1,409	1,310	1,056	957	1,013	991
	DFIT	HSM	Existing 100 hp 12000 rpm	9" Rough & Finish	986	ı	437	1	l	t
	RETROFIT	CONV.	Existing 100 hp 3600 rpm	9" Rough & Finish	945	l	725.	ı	1	t
		PRESENT	Existing 20 hp 3600 rpm	5½" Rough & Finish	3,958	1	ı	ı	1	1
			(XXX) values not limited by load/ unload times	Cutters→ PARAMETERS	One Spindle One Panel Length Table	Two Panel Length	Two Spindle One Panel Length	Table	Four Spindle One Panel Length	Two Panel Length

Summary of Combined Total Machine Investment Plus Labor Cost (\$) Per 5,376 Panels Table 4-6.

4-6.4 Comparison of Monthly Panel Machining Capacities of Various Machine Tool Configurations

Table 4-7 shows the projected monthly panel machining capacities of the 41 different machine tool configurations. Details are compiled in Appendix C. The information in Table 4-7 is based on a 100 percent efficiency factor after operator break, fatigue, and personal time have been allowed.

Additional time should be allocated for maintenance (commonly 10 percent or higher for conventional numerical control machining centers) and other miscellaneous reasons. Furthermore, in this study no time has been allowed for secondary machining operations such as drilling and tapping holes while the part is still mounted on the machine. A realistic estimate of actual productive machine time for the milling operation would be 80 percent. Table 4-8 shows the projected monthly panel machining capacities of the 41 machine tool configurations at this 80 percent level.

4-6.5 Selection of Best Alternative Machine Configurations Criteria used for selection were:

- a) The machine must meet or exceed the production requirement of 64 panels per month (using the 80 percent efficiency level).
- b) The panels must be produced at the least reasonable combined total machine investment plus labor cost.
- c) The machine tool configuration must be reasonably well proven.

Table 4-9 shows the 15 machine tool configurations selected which are expected to meet or surpass the 64 panel per month production requirement. In addition to the monthly panel capacity, the combined total machine investment and labor costs are shown. Eight of the 15 configurations involve the 150 hp, 24,000 rpm spindle which at this time is felt to need further proofing before it can be recommended. Table 4-10 shows the machine tool configurations selected for each of the three following major categories.

a) Retrofit HSM

Two present gantry type milling machines (each retrofitted with two 100 hp, 12,000 rpm vertical spindles) show a combined projected panel machining capacity of 86.6 panels per month at an estimated labor plus additional investment cost for the retrofit of \$4,704,000 or \$875 per panel.

Estimated Panel Machining Capacities of 41 Machine Tool Configurations -Panels/Month Table 4-7.

											OF I	PUU	יט ח	U					 	
ency Level			ISM)	Vertical	Spindle 150 hp 24060 rpm	2" Rough 9" Finish		50.6	94.8		0.69	108.5	(189.7)		104.7	144.7	(379.4)		_	
100 Percent Efficiency Level	SI		SPEED MACHINING (HSM)	Vertical	Spindle 150 hp 24000 rpm	9" Rough & Finish		52.1	100.1		70.4	108.5	(2000.2)		106.2	144.7	(399.9)	•		
100 Perc	CONFIGURATIONS	NEW	HIGH SPEED M	Vertical	Spindle 100 hp 12000 rpm	9" Rough & Finish		37.4	57.0		55.6	108.5	(114.1)		87.0	144.7	(218.0)			
	MACHINE TOOL CO		1	Vertical	Spindle 75 hp 9000 rpm	9" Rough & Finish		32.3	45.9		49.7	91.8			77.6	144.7	(167.3)			
	MACI		FIONAL	Vertical	Spindle 150 hp 3600 rpm	9" Rough & Finish		22.1	27.8		36.8	55.6			62.3	109.4				
			CONVENTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish		19.6	23.9	•	33.1	47.7			56.8	93.6				
		RETROFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish		36.1	ı		54.1	ı			í	ţ				
		RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish		19.5	i		35.0	ı			1	1				
			PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish		4.9	ı	- <u> </u>	ı	ı			1	ı	•	,		
-		(XXX) values not	limited by load/	unload times		Cutters→ PARAMETERS	One Spindle	One Panel Length Table	Two Panel Length Table	Two Spindle	One Panel Length	Two Panel Length Table		Four Spindle	One Panel Length Table	Two Panel Length				

Estimated Monthly Panel Machining Capacities of 41 Machine Tool Configurations (Number of Panels) Table 4-8.

									OF	POO	R QU	ALI	TY				ט-ט	8228		
Level			(HSM)		Vertical	Spindle 150 hp	2" Rotzh 9" Finich	1071177	40.5	75.9			55.2	86.8	(151.7)		83.8	115.7	(303.5)*	
Operation) Efficiency]	MS		MACHINING (1		Vertical	Spindle 150 hp 24000 rom	9" Rough		41.7	80.1			56.3	86.8	(160.1)		85.0	115.7	(319.9) *	
(Two Shift Operation) 80 Percent Efficiency Level	COMFIGURATIONS	NEW	HIGH SPEED N		Vertical	Spindle 100 hp 12000 rom	9" Rough		29.9	45.6			44.5	8.98	(91.2)		9.69	115.7	(174.4)*	
	MACHINE TOOL C			•	Vertical	Spindle 75 hp 9000 rpm	9" Rough		25.8	36.7			39.8	73.5			62.1	115.7	(133.8) *	
	MAC		LIONAL		Vertical	Spindle 150 hp 3600 rpm	9" Rough & Finish		17.7	22.2			29.4	44.5		*	8.67	87.6		
,			CONVENTIONAL	Horiz.	for Rough Vert. for	100&150. hp 3600 rpm	14" Rough 9" Finish		15.6	19.1		,	26.5	38.2			45.5	74.9	Α	
		RETROFIT	HSM		Existing	100 hp 12000 rpm	9" Rough & Finish		28.9	1			43.3	1			1	ı		
		RETH	CONV.		Existing	100 hp 3600 rpm	9" Rough & Finish		16.7	ı		, 6	78.0	ı			1	ſ		
			PRESENT		Existing	20 hp 3600 rpm	5½" Rough & Finish		3.9	ı	,	•	ı	1			1	ì		
· <u>-</u>	(XXX) values not limited by load/	unload times	*(XXX) values not	timited by gantry speed			Cutters→ PARAMETERS	One Spindle	One Panel Length Table	Two Panel Length Table	Ē	One Danel Longth	Table	Two Panel Length Table		Four Spindle	One Panel Length Table	Two Pane. Length Table		

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Estimated Panel Machining Capacities and Combined Costs (\$) of 15 Machine Tool Configurations Meeting 64 Panel Per Month Requirements Table 4-9.

	MSC	. D-	.059	359					OF	POOR	QU	ALITY	,			
iciency Lev			(HSH)	() de	Spindle 150 hp	24000 rpm 2" Rough	y rinish		i L	/5.9 \$2,752K			86.8 \$2,866K	5	83.8 \$3,599K	\$3,633K
80 Percent Efficiency Level	SNC		SPEED MACHINING (Verrical	Spindle 150 hp	9" Rough	ustuta 6		- 0	\$2,693K			86.8 \$2,866K	, , ,	\$3,588K	\$3,633K
80	CONFIGURATIONS	NEW	HIGH SPEED	Vertica1	Spindle 100 hp	9" Rough	HETHET 5						86.8 \$3,466K	9 09	\$4,208K	\$4,091K
	MACHINE TOOL			Vertical	Spindle 75 hp	9" Rough							73.5 \$3,343K		115.7	~
	MAC		CONVENTIONAL	h r Vertica]	Spindle p 150 hp 3600 rpm	5, 40									87.6	\$4,464K
			CONVE	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish									74.9	\$5,331K
		RETROFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish									-	
		RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish	•									
			PRESENT	Existing	20 hp 3600 rpm	5½" Rougl & Finish	•									
-						Cutters+ PARAMETERS		One Spindle One Panel Length Table	Two Panel Length Table		Two Spindle	One Panel Length Table	Two Panel Length Table	Four Spindle One Panel Length	Table Two Panel Length	บ
						PARA		One Spir			Two S	One Par Table	Two Par Table	Four S	Two Par	rable

2" Rough 9" Finish 24000 rpm Vertical Spindle 150 hp ORIGINAL PAGE 13 OF POOR QUALITY (HSM) 24000 rpm Vertical 9" Rough & Finish HIGH SPEED MACHINING Spindle 150 hp MACHINE TOOL CONFIGURATIONS 12000 rpm 9" Rough & Finish Vertical Spindle 86.8* 115.7 * NEW 100 hp \$4,091K (@\$761) \$3,466K (@\$645) 9000 rpm \$3,343K (@\$622) 9" Rough Vertical 6 Finish BEST Spindle 75 hp 73.5* 3600 rpm Vertical Spindle 150 hp 9" Rough & Finish \$4,464K 87.6 * @\$830) CONVENTIONAL CONVENTIONAL 14" Rough 9" Finish Vert. for 100£150 hp for Rough Finish 3600 rpm Horiz. BEST 12000 rpm Existing 100 hp 9" Rough \$4,704K (@\$875) & Finish HSM ROFIL (2 Machithes) RETROFIT BEST RET 100 hp 3600 rpm Existing 9" Rough & Finish CONV. 20 hp 3600 rpm 512" Rougi Existing PRESENT & Finish Cutters→ in panels/month *Total capacity Onc Panel Length Two Panel Length One Panel Length Two Panel Length Table Four Spindle Two Spindle PARAMETERS Table Table Table

4-29

Recommended Machine Tool Configurations vs Total Cost and Cost Per Panel. Table 4-10.

It is assumed that two saddles for mounting the spindles will be available on each machine and that the new Allen Bradley #7320 controls recently installed on the machine are capable of controlling the two spindles simultaneously as reported.

b) New Conventional

The best choice for a <u>new conventional</u> machine is a two panel wide, two panel long gantry type machine with four 150 hp, 3,600 rpm vertical spindles. This configuration is projected to have a panel machining capacity of 87.6 panels per month and have a combined total machine investment plus labor cost of \$4,464,000 or \$830 per panel.

c) High Speed Machines (HSM)

Five different machine configurations appear to meet all three of the selection criteria. Three configurations were identified involving the the least cost.

The two best choices are both gantry type milling machines with two spindles and a single width, double length table. The two 100 hp, 12000 rpm vertical spindle machine provides a capacity of 86.8 panels per month at an estimated combined machine investment plus labor cost of \$3,466,000 or \$645 per panel.

The other best choice machine has two 75 hp, 9,000 rpm vertical spindles, a capacity of 73.5 panels per month and is estimated to have a combined machine investment plus labor cost of \$3,343,000 or \$622 per panel.

The third lowest cost producing HSM configuration is the two panel wide, two panel long, gantry type machine with four 100 hp, 12,000 rpm vertical spindles. This machine has a projected panel machining capacity of 115.7 panels per month at an estimated combined investment plus labor cost of \$4,091,000 or \$761 per panel.

4-7 IMPLEMENTATION PLANS

Before a decision on retrofitting existing equipment or purchasing new is made, careful attention should be paid to several factors. Time should be allowed in the implementation schedule for a detailed vibration analysis of the present

or other machine being considered for retrofitting. Estimated vendor delivery times should be confirmed since delivery schedules can very noticeably with work load.

The following factors are involved and should be considered before the new or retrofit machine is fully ready for operation.

Retrofit Machine

The information in Figure 4-7 is provided as a guide for scheduling for a retrofit HSM system to be installed on the present machine.

If a retrofit were to be made on this machine, schedule and budgetary provisions should also be provided for the updating of the electrical power supply and other items described in Section 5. The overall time from placing of order to full production readiness is expected to approach 12 months.

New Conventional or HSM Machine

A scheduling and planning guide is provided in Figure 4-8 to be used for the procurement, installation and readying of either a new conventional or HSM machine. The lead times estimated by the machine tool builders contacted were essentially the same for either type of machine. However, some variation should be expected from particular machine tool builders. The overall time from placing of order to full production readiness is expected to be at least 18 months.

Other Considerations

Other activities should take place concurrent with the installation. For example, specific cutter determination and NC programming should be established.

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MODEL PLAN TITLE ISSUE NO. REFERENCE 4-8.	OPERATION		PURCHASE ORDER	MACHINE DELIVERY	FOUNDATION EXCAVATION	FOUNDATION-STEEL, CONCRETE AND CURE	MACHINE INSTALLATION	DEBUG MACHINE SOFTWARE	DEBUG & IMPLEMENT POST PROCESSOR	ACCEPTANCE TESTING	MACHINE READY FOR USE							FORM LMSC 481-3 Diazo Reproducible	

SECTION 5

GENERAL DISCUSSION

5-1 COMPARISON WITH TASK B PROJECTED MACHINING TIMES

The 6.0 hours machining time projected from the 4 foot by 8 foot panel machined in Task B (Table 6-1 of the Task B report) for the Cincinnati Milacron 75 hp single spindle machine compares very closely to the 5.9 hours total machining time estimated for the 75 hp, 9,000 rpm spindle machine (Table 4-2). The 4.48 hours projected in Task B for the 100 hp, single spindle machine also compares very closely to the 4.75 hours total machining time determined in Task A. The estimates in Task A and Task B were similar even though computed using different procedures.

5-2 PRODUCTION RATE OF PRESENT MACHINE

The 3.9 panel per month baseline production rate of the present machine is relatively low and is obviously limited by the low (20 hp) spindle motor. A more realistic baseline might be 16.7 panels per month projected as obtainable with a retrofit 100 hp, 3,600 rpm spindle (Figure 4-8). The 3.9 panel per month baseline production rate was calculated using current parameters for metal removal and assuming the starting stock to be 1.75 inch thick solid plate.

5-3 RETROFIT OF PRESENT MACHINE

When considering conversion of the present gantry type mill to HSM, the following decision making criteria should be included.

- a. The current capital investment value of this machine was not included in this study. Only the additional retrofitting cost was considered.
- b. The machine is approximately 20 years old but has been recently rebuilt and a new control has been added.
- c. The present electrical power supply to the machine is reportedly capable of handling only 13 hp and will probably need to be replaced.
- d. The gantry should operate at 200 ipm. Reportedly it can be operated currently at a maximum of 150 ipm. This limitation would need to be remedied.
- e. Before a final decision to retrofit with large, powerful spindle motors is made, a detailed vibration analysis should be performed to insure a fully functional system. The presence of the current single 20 hp motor instead of two 100 hp motors (reportedly original equipment) may indicate problems of lack of rigidity and resulting vibrations.

f. A chip removal system should be defined and provided.

5-4 SELECTION OF GENERAL MACHINE TOOL CONFIGURATIONS

The best choice of the general machine configurations based on production capacity, labor cost, and machine investment cost is the two panel length, gantry type machine with two vertical spindles. Although the vertical panel machine concept has better chip removal characteristics, none of the machine tool builders contacted felt that it would be feasible to move the tall column required for an 11 foot wide panel at the feed rates desired for HSM.

The 100 hp, 12,000 rpm spindle is the best choice of spindle. The projected production capacity should be adequate and could be increased if the loading and unloading time were reduced.

The 150 hp, 24,000 rpm spindle coupled with the 1,000 ipm gantry feed is theoretically capable of considerably higher production rates than the lower rpm machines but the proposed designs need to be more fully proven. Furthermore, cutters are not yet available which would allow full utilization of machine potential.

The second choice of spindle is the well proven 75 hp, 9,000 rpm version. However, the monthly production capacity of this machine is somewhat lower than for the 100 hp, 12,000 rpm spindle.

Of the 41 machine configurations compared, 15 would be capable of meeting the capacity requirements of 64 panels per month at varying combined labor plus machine investment costs. However, eight of the 15 configurations involve the 150 hp, 24,000 rpm spindle which needs to be further proven.

5-5 CUTTERS

The study was based on the assumption that cutters are available (or shortly will be) which are capable of operating at the cutting speeds of interest. Availability was based on contacts with machine tool builders and cutter manufacturers. However, for the highest cutting speeds indicated (especially 56,549 sfpm) cutters are definately not yet available.

5-6 CHIP REMOVAL

The volume of chips produced is in direct relationship to the machining metal removal rate. At the very high metal removal rates under study, the removal requirements for the chips becomes significant and dictates a need for mechanized systems for chip removal.

The most highly recommended chip removal method for the gantry type milling machines is by vacuum. The chips are collected from an inlet located at each cutter and conducted to a common disposal point where coolant is reclaimed. The cost of such a system is estimated to be from \$350,000 to \$400,000 per machine. The cost for a chip removal system has not been included in the machine investment cost figures in this study.

Section 6

CONCLUSIONS

6-1 MACHINE TOOL CONFIGURATIONS

Based on the required 64 panel per month production rate (for 5,376 panels), the following machine tool configurations, cost savings and production rates are projected:

- a. High Speed Machine (1) with (2) State-of-the-Art 75 hp High Speed Spindles.
 - o \$17,935,000 Cost savings
 - o 73.5 panels per month rate
- b. High Speed Machine (1) with (2) Advanced 100 hp High Speed Spindles
 - o \$17,812,000 Cost savings
 - o 86.6 panels per month rate
- c. New Conventional High-Capacity Machine (1) with (4) Conventional 150 hp Spindles
 - o \$16,814,000 cost savings
 - o 87.6 panels per month rate
- d. Retrofit for (2) Existing Machines each with (2) Advanced 100 hp High Speed Spindles
 - o \$16,574,000 cost savings
 - o 86.6 panels per month rate

6-2 PROVEN HSM EQUIPMENT

Using proven HSM equipment, production rates could be increased from a baseline of 3.9 panels per month to 73.5 panels per month. The equipment used would be a one panel wide, two panel long gantry type mill with two 75 hp, 9,000 rpm spindles. The combined labor plus machine investment cost would be reduced from \$3,958 to \$622 per panel. The total estimated savings of 5,376 panels would be \$17,935,000.

6-3 ADVANCED HSM EQUIPMENT

Advanced HSM equipment (not fully proven but at a high confidence level) would increase production rates from the current 3.9 panels per month to 86.6 panels per month. Equipment would be a one panel wide, two panel long gantry type machine with two 100 hp, 12,000 rpm vertical spindles. Labor plus machine investment cost would be reduced from a baseline of \$3,958 to \$645 per panel and estimated savings (on 5,376 panels) would be \$17,812,000.

6-4 MAXIMUM PANEL AND SPINDLES BENEFITS

A two panel vide, two panel long gantry type machine with <u>four 75 hp or greater</u> <u>HSM vertical spindles</u>, would increase production rates from 3.9 panels per month to 115.7 panels per month (limited by load and unload time). The combined labor plus machine investment cost would be reduced from a baseline of \$3,958 to \$769 per panel for four <u>75 hp</u>, <u>9,000 rpm</u> spindles and have a projected total savings of \$17,142,000 for 5,376 panels. A comparable reduction with four <u>100 hp</u>, <u>12,000 rpm</u> spindles would be from the baseline of \$3,958 to \$761 per panel at a projected total savings of \$17,187,000.

6-5 RETROFITTING WITH HSM SPINDLES

Production rates could be increased from 3.9 panels per month currently to an estimated 43.4 panels per month by retrofitting two 100 hp, 12,000 rpm

HSM spindles on the present gantry type mill. Two machines thus converted would be needed to achieve the 64 panel per month production requirement. The projected combined labor plus additional retrofitting machine investment cost (two machine) would be reduced from baseline \$3,958 to \$875 per panel for a total savings of \$16,574,000 on 5,376 panels.

6-6 NEW CONVENTIONAL MACHINE

A <u>new conventional machine</u> could be used to increase production rates from 3.9 currently to 87.6 panels per month. This could be accomplished with a two panel wide, two panel long gantry type machine and four 150 hp, 3,600 rpm spindles. The projected combined labor plus machine investment cost would be reduced from baseline \$3,958 to \$830 per panel at a total estimated savings of \$16,814,000 on 5,376 panels.

6-7 DEVELOPMENT HSM SPINDLES AND 1,000 IPM FEEDS

Extremely high production rates were indicated through use of HSM with 150 hp, 24,000 rpm spindle machines with 1,000 ipm gantry feed. However, these machines (and cutters to utilize their full potential) are not sufficiently proven to be recommended in this study. The potential of such a machine however, indicates an \$18,106,000 cost savings (5,376 panels) for a four (4) spindle, two panel width, two panel length configuration. With unrestricted gantry speed and load/unload times, production rates of 320 panels per month were projected!

6-8 HORSEPOWER EFFECTS

Horsepower was the dominant factor regarding the metal removal rate during the rough machining operation regardless of rpm or cutting speed (sfpm).

6-9 DOMINANT FACTORS - METAL REMOVAL RATE

Rpm and gantry feed (ipm) were the dominant factors regarding the metal removal rate during the finishing operations. The production capacity of the machines increased as rpm and gantry feed were increased.

6-10 ADDED TABLE LENGTH

The addition of the second table length to allow machining to continue during loading and unloading, increased the production capacity and decreased the cost per panel in all isstances.

6-11 LOAD/UNLOAD TIME

Loading and unloading time became a limiting factor at the high production capacities even for the two panel length machines.

6-12 HORIZONTAL VS VERTICAL SPINDLES

The machines with horizontal spindles for rough machining and vertical spindles for finish machining showed a lower production capacity and higher cost per panel than for comparable machines with vertical spindles only.

6-13 PANEL MOUNTING

Machines with vertical mounting of panels would appear to be best suited for convenient chip removal. At the current state of development, however, travel rates for the moveable columns are not competitive with the gantry type machines.

6-14 CHIP REMOVAL

Chip removal is a very important consideration. Currently, the most highly recommended system for large horizontal panels utilizes vacuum removal techniques that are proven and in use on other applications and that can handle without problem the large chip volumes typical of hsm.

APPENDIX A

MACHINING OPERATION TIME

A-1	Rough Mill Pockets
A-2	Finish Mill Bottom of Pockets
A-3	Mill T-Ribs
A-4	Mill Edge of Tie and Padii

Determination of Machining Operation Time: Rough Mill Pockets Table A-1.

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		HINING	Verrical Spindle	150 hp 24000 rpm	2"Rough 9" Finish	2	ന	200-	m	15	.508	લ	1.016	504	512	128.0	12,566	1.426
Spfndle)		H SPEED MACHINING	Vercical Spindle	150 hp 24000 rpm	2" Rough & Finish	6	æ	(3005)	23	23	990*	6	.597	(1000)	593	149.2	56,549	(1.220)
(Based on One Si	NEW	нтсн	Vertical Spindle	100 np 2,000 rpm	9" Rough & Finish	55	80	200.	22	22	690.	6	.624	636	397	99.2	28,274	1.716
(B)			Vertical Spindle	9,000 rpm	9" Rough & Finish	6	∞	.007	23	23	990°	6	.594	200	297	74.3	21,206	2.368
MAC		FIONAL.	Vertical Spindle	3600 rpm	9" Rough & Finish	6	∞	.007	5	S	2.8 max.	6	2.745	202	549	137.0	8,482	1.295
		CORVENTIONAL	Horiz. For Rough Vert. for Finish	3600 rpm	14" Rough 9"& Finish	14	∞	.007	E	12	2.8 (Max.)	.508	1.422	202	287	71.8	13,195 8,482	2.766
	RETROFIT	HSM	Existing	12000 rpm	9" Rough & Finish	6	∞	.002	7	7	.218	6	1.962	200 max	392	98.1	28,274	1.813
	RETR	CONV.	Existing	3600 rpm	9" Rough & Finish	6	80	.007	7	7	.218	6	1.962	200 max	392	1.86	8,482	1.813
		PRESENT	Existing 20 hp	3600 rpm	5½" Rough & Finish	5-1	4	8000.	4	80	.475 max	5.25	2.494	12	30	13 max	4,948	32.256
(XXX) values	limited by travel feed restrictions				Cutters→ PARAMETERS	Cutter Diameter (in)	No. of Teeth		No. of Layers	No. of Passes per Pocket	Depth of Cut (axial)	Depth of Cut (radial)	Cross-Section/Pass (sq. in.)	Table Feed Used (ipm)	Cu. In./Min.	Horsepower Required	Cutting Speed (sfpm)	Time Required (hrs)

Determination of Machining Operation Time: Finish Mill Bottom of Pockets (9" Diameter Cutter, .. 100" Deep Except "Present" at CPC) Table A-2.

an.		,			•	(Ba	(Based on One	on One Spindle)	
					NACIIINE	TOOL	CONFIGURATIONS	S	
		RETROFIT	DFIT				NEW		
	PRESENT	CONV.	HSM	CONVENTIONAL	TONAL	**	HIGH SPEED M	MACHINING (H	(HSM)
				Horiz. for Rough		·			
	Existing	Existing	Existing	Vert, for Finish	Vertical	Vertical Spindle	Vertical Spindle	Vertical Spindle	Vertical Spindle
	20 hp 3600 rpm	100 hp 3600 rpm	100 hp 12000 rpm	100&150 hp 3600 rpm	150 hp 3600 rpm	75 hp 9000 rpm	100 hp 12000 rpm	150 hp 24000 rpm	150 hp 24000 rpm
Cutters→	5½" Rough	9" Rough & Finish	9" Rough & Finish	14" Rough 9" Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	2" Rough 9" Finish
Cutter Dia. (In.)	5-1/4	6	6	6	6	6	6	6	6
No. of Teeth	7	8	∞	8	80	œ	&	80	∞
Chip Load	8000	.003	*005*	.003	.003	.003	.003	.003	.003
No. of Layers		н	H	H	H	 -	-	٦	н
Total Passes/Pocket	2	H	H	p=4	П	-1	1	H	Н
Depth of Cut (Axial)	5.25	.100	.100	.100	001.	.100	100	.100	.100
Depth of Cut (Radial)	.100	6	6	6	6	6	6	6	6
Cross-Section/Pass	.525	006.	006.	006.	,306.	006.	006.	006.	006.
Table Feed Used	12	98	200∗	98	98	216	288	576	576
Cu.in./min.	6.3	77	180*	77	77	194	257	515	515
Horsepower Required	1.6	19.4	45*	19.4	19.4	48.4	64.4	129	129
Cutting Speed (sfpm)	4,948	8,482	28,274	8,482	8,482	21,206	28,274	56,549	56,549
Hours Required	8.064	.593	.259*	.593	.593	.243	.181	. 084	780
								٠	
*Reduced due to table	feed limit	feed limitation of 20	0 jpm.						
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Determination of Machining Operation Time: Mill T-Ribs (Based on One Spindle) Table A-3.

							MACII	INE TOOL CO	MACHINE TOOL CONFIGURATIONS	žš	
			RETROFIT	OFIT					NEW		
		PRESENT	CONV.	HSM	NOO	CONVERTIONAL	7		HIGH	H SPEED MACHINING	HINING
		Existing	Existing	Existing	Horiz. for Rough Vert. for		Vertical	Vertical	Vertical	Vertical	Vertical
		20 hp 3600 rpm	100 hp 3600 rpm	100 hp 12000 rpm	Finish 100&150 hp 3600 rpm		Spindle 150 hp 3600 rpm	Spindle 75 hp 9000 rpm	Spindie 100 hp 12000 rpm	Spindle 150 hp 24000 rpm	Spindle 150 hp 24000 rpm
	Cutters+	5½" Rough & Finish	9" Rough & Finish	9" Rough & Finish	14" Rough 9" Finish	6 3	Rough Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	2" Rough 9" Finish
	Cutter Diameter (in)	7	7	4	7	4		7	7	7	7
A-	No. of Teeth	9	7	7	7	4		7	7	7	4
-4	Chip Load (in.)	6100.	.003	.003	.003	.003	33	.003	.003	.003	.003
	No. of Layers	2	2	2	2	2	<u> </u>	2	2	2	2
	Total # of passes/ Rib	7	4	4	7			7	7	4	4
	Depth of Cut (axial)	.725 max.	.725	.725	.725	.725	55	.725	.725	.725	.725
•	Depth of Cut (Radial	.575	.575	.575	575.	.575	.5	.575	.575	.575	.575
	Cross - Section/Pass (sq. in.)	.417	.417	.417	.417	.417	7.	.417	.417	.417	.417
	Table Feed Used (ipm)	40	43	144	67		43	30£	144	288	288
	Gu. In./Minute	17	18	09	18		18	45	09	120	1.20
	Horsepower Required	4.3	4.5	15.0	4.5	4.5	κĴ	11.3	15.0	30.0	30.0
	Cutting Speed (sfpm)	3,770	3,770	12,566	3,770	3,770	07.	9,425	12,566	25,133	25,133
	Hours Required	4.838	4.493	1.382	4.493	3 4.493	693	1.728	1.382	jumet ten. / to Year	## ## # * *

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*Assumed Value PRESENT Existing 20 hp 3600 rpm Cutters 5½" Rough	RETROFI	OFIT	•					
ters+						NEW		
en 101	CONT	HSM	CONVERTIONAL	TONAL		HIGH	SH SPEED MACHINING	HINING
	Existing	Existing	Horiz. For Rough Vert. for	, Vertical	Vertical.	Vertical	Vertical	Vertical
	100 hp 3600 rpm	100 hp 12000 rpm	Finish 100£150 hp 3600 rpm	Spindle 150 hp 3600 rpm	Spindle 75 kp 9000 rpm	Spindle 100 hp 12000 rom	Spindle 150 hp 24000 rpm	Spindle 150 hp
	9" Rough & Finish	9" Rough & Finish	14" Rough 9" Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	2" Rough 9" Finish
Cutter Diameter(in) 2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
**	7	ণর	7	7	4	7	7	7
Chip Load (in) .0028	.003	.003	.003	.003	.003	.003	.003	.003
No. of Layers	-	rI	H	٦	H	-		-
Total # of Passes/ 2	2	2	7	2	2	2	2	2
Depth of Cut 1.125 (Axial)	1.125	1.125	1.125	1.125	1.125	1.125	1.125	1.125
Depth of Cut (Radial) (in)	.296	. 296	.296	.296	. 296	. 296	.296	.296
Cross - Section/Pass .333 (sq. in.)	.333	.333	.333	.333	.333	.333	.333	•333
Table Feed Used 40	43	144	43	43	108	144	288	288
Cu. In./Min. 13	14	84	14	14	36	85	96	96
Horsepower Required 3.3	3.5	12.0	3.5	3.5	0.6	12.0	24.0	24.0
Cutting Speed 2,356 (sfpm)	2,356	7,854	2,356	2,356	5,891	7,854	15,708	15,708
Hours Required 2.419	2.246	.691	2.246	2.246	.864	.691	.346	.346

Determination of Machining Operation Time: Mill Edge ωf T's and Radii (Based on One Spindle) Table A-4.

APPENDIX B

MACHINE RUN CALCULATIONS

B-1	Present Method - 20 HP, 3600 RPM
B-2	9 inch Cutter 8 Teeth, Retrofit 100 HP, 3600 RPM, 200 IPM
B-3	9 inch Cutter 8 Teeth, Retrofit 100 HP, 12000 RPM, 200 IPM
B-4	14 inch Cutter (Roughing), 9 inch Cutter (Finishing) 100 HP and 150 HP
B-5	9 inch Cutter 8 Teeth, 150 HP, 3600 RPM
B-6	9 inch Cutter 8 Teeth, 75 HP, 9000 RPM
B-7	9 inch Cutter 8 Teeth, 100 HP, 12000 RPM
B-8	9 inch Cutter 8 Teeth, 150 HP, 24000 RPM

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Table B-1 Present Method - 20HP (13 2. Th. , 3300 RPM

	MACHINE RUN CALCU	LATI	ONS	· · · · · ·				
ITEM NO.	ELEMENT DESCRIPTION	CUT- TER	LOC.	APP +OT b	TOT. LOC. c	STD. HRS./ INCH d	OCC e	MACH. TIME e
	Mill Top of Tee 1 Pass	3位			240,22	, 2014	12.	7,032
	12 ipm Rough Mill Pocket 4 Layers X 2 Passes	51/4			24713	.0014	8×12	32.256
	Finish Mill Pocket 2 Passes	5/,			240.00	1,0014	2 X /2	2,234
	12 ipm Mill Under T-Rio 2 Passes	14	<u> </u> 		1240,30	1.20042	IS XS.) -1,2,3,3
	40 ipm (.0019"chip load) 6 teeth	1			1			1
	Mill Edge of Tee 1 Pass 40 ipm (Assuming 4 Teeth)	27.81	1	<u> </u>		 `???45	l	2.474
	Mill Periphery 1 Pass 40 ipm (Assuming 4 Teeth)	21/251	1		6/3.03	2:-ودد.	i	,256
	Mill Taper on Tee / Pass	2"5M			3.50	,00055	24	,040
	30 ipm	+	 	-	1		229	
							- 4	
	Millina Time	 		 				57.90
	Cutter Reposition Total Mac	V	J 77.				1225	52.46
	(Using 4/2	yers	H-For	youa	hina)			
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	le 2-2 7" cutton, 2 Touth	ta Paranga ta a	- 11		20 R			* * * ;	
	MACHIN	E RUN CALCI	JLATI	ONS					
ITEM NO.	ELEMENT DESCRIPTION		CUT- TER	LOC.	APP +OT b	TOT. LOC.	STD. HRS./ INCH d	0CC e.	MACH TIMI e
	Mill Top of Ten	1 Pass	7"			240,00	, 35010		, 2%,
•	86 ism.				· .				
	Rough Mill Pocket	7 Layers	1311		 	240.00	.5000023	7×13	1.31.
	Finish Mill Pocket	1 Pass	 	ļ		243.30	. 53319	1 1 1 7 2	. 5
	86 ipm								
	Mill T-Rib		14"	<u> </u>	 	243,33	1,22539	2834	4,-1
	43 ipm 4 Teeth Mill Edge of Tee		21/2"		<u>!</u>	270.30	1.00039	24	2.2.
	43 iom 4 Teeth			1				1	51174
	Mill Periphery		21/2"			610.00	,00039	1	, 2
	43 ipm 4 Teeth Mill Taper on Tee 30 ipm 4 Teeth	1 Pass	la "			7 1	.00055	21	0
	30 ipm 4 Teeth		<u> </u>		 	1	,00033	1 7	1 , 5 .
				1					
	Milling Time			1	<u> </u>	1		713	
			 		 -		<u> </u>	1	7, 7
	Cutter Repo	sition		.002.	5	X	1	239	1,5
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<u>'</u>		ACKININA I		1/41-47					
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	MACHINE	RUN CAL	CULATI	ONS					
ITEM NO.	ELEMENT DESCRIPTION		CUT- TER	LOC.	APP +OT b	TOT. LOC. c	STD. HRS./ INCH d	0CC e	MACH. TIME e
	Mill Top of Tee	I Pass	311			230,33	, ೨೦೦೩ನ	12	, 233
	794 200 lam (1002" c	hip load)							
	Rough Mill Pocket (.002" =	7 Layors	17"		<u> </u>	240.00	.300023	TXIZ	1.813
	672 200 lpm (.002" =	hip load:		<u> </u>	ļ				
	Finish Mill Backet	1 Pass	13"		<u> </u>	240,00	1000027	1/3	3.7
<u> </u>	-288 200 ipm			<u> </u>	 				<u> </u>
	Mill T-Pile		[£!'z''	 	 	2 1 1, 13	. 30 x tt		<u> '</u>
	144 IBM Mill Edge of Toe		21/2"		 	2 1 1 1	.33312	2	
	17:11 Edge of Tee			 		740.23	,33312	1 3 18 1 2	137/
	144 ipm Mill Periphery		272"		┼	112 00	.333/2		1,37:
	7 IVIII PERIPHETY	A	- ^ ' -	 	 	13/0/09	• 334 (=	/	1
	Mill Taper on Tee		2"		 	3.03	,)) 0 5 5	54	1.34
	30 ipm						,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	 	1
				İ				215	1
	Milling Time			1		1			14.49
	Cutter Reposition			1.0025	+	X	l	209	
	Total Machinin	a Time	(hlus)			1		1	5.02
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				<u> </u>	<u> </u>	-		!	
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	NOTE: The crossed out feed r			!	 	 	 	<u> </u>	
	reduced due to the 200			1	-	!		[-
	gantry feed limitation	1.			 	! -			
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	B-4 /4"Wheel Cutter (Roughing), 9 MACHINE RUN CALCU	11 ATT	ONS	· · · · · ·	5	3 3 3 A	1:1	
	MACHINE RUN CALCE	JLAII		,				
			}			STD.		
ITEM		CUT-		APP	TOT.	HRS./	200	MACH
NO.	ELEMENT DESCRIPTION	TER				INCH		TIME
			a	Ь	С	d	e.	e
	Mill Top of The 1 Pass	2/2			240.70	,20027	7.0	بهتي
	43 ipm 4 Flute							
	Rough Mill Pocket 3 layers x 4 Passes	1/4"21	1	<u> </u>	<u> </u>	. ၁५०७८	12 12	2.766
	202 jom 8 Teeth Finish Mill Packet 1 Paga	+	 	 -				 ;
	Finish Mill Packet 1 Pags 43 jpm 7 Teeth	17		 -	1 - 3.53	و د دروز ر		
	Mill Under T-Pin = Freeze	14	 		1.243.50	1.0005?		2 2 3
	43 lam 4 Teeth at ,003" chip Load	1	i	1	1			
	43 ipm 4 Teeth at ,003" chip Load Mi Ease of Tee / Pass 43 ipm 4 Teeta Mill Parishery / Pass	S/2 EM	1		ددردام	,00039	24	2,24
	43 ipm 4 Toe-	1						
	MIII Periphery 1 Pass 43 Irm 4 Touth	12/2/61	1	 	310,00	,39359		1.25
	Mill Taper on Tee / Pass	12"EN	1			, 2025-		
	30 ipm	1- 5"	1		1,00	جي عددر,		1 24
		1	 				265	
			j	1			49.9	
	Milling Time (200 ipm)	1			!			10.9
	Cutto- Reposition Cfor 4 Spir	valle 1	achine	(5)	0025	X	266	.6
	Total Mas	<u>thining</u>	Time	 (ars	D C4	PINdle	(5)	11,50
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		 	i 				`	<u>'</u>
	Milling Time (300 ipm for 10	12 S	dinde	Maci	hinesi		i	10.7
	Cutter Reposition	1	1		100167	X	266	
	Total Mas	Hining	Tim	<u> </u>	<u> </u>			11.3
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Table 2-5 7" DIA. War 1, Ton 7 Time 150 MP. BASATILL MACHINE RUN CALCULATIONS STD. APP TOT. HRS. IMACH. CUT-ITEM TER | LOC. | +OT | LOC. | INCH | OCC | TIME **ELEMENT DESCRIPTION** NO. a Č d e 1 e , **)** ii Mill Tox of Turn 1 Pass 도록3,3회,3 . S. 시 2 Teath 25 10 mg 5 2 3 3 3 5 5 2 6 7 3 3 4 2 3 6 Stand Bull Land J. Training 202 / [2:3] [* 1 '. · 1 . Fluid Will Hadret 13 free . 1240,00, 2007 12 . 2-4 2.4 1 7 74020 H3 12m 240,30 1. 3652 1 24 2,24 5 East of This 1 Paci 4 Teeth 12 1 pm (3.30), 33637 / 1.232 Mill Periphery 4 Teeth 1 Pro-S' SM 86 low 2"EM 12,001,00088 241,040 Mill Taper on Tee / Pas: 20 ipm Machining Time / Spindle For 4 Spindle Machines (230/om) 7.452 1,00=5 X Cutter Pagestition The in Chas Machining Time/Spindle for I or 2 Spindle Machines (3100 ipm): Milling Time Cutter Reposition 1/83 | ,500 1.00/67 X 19.753 Total Machining Time (hids) FTOTAL MACHINE RUN -

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	MACHINE RUN CALCU	LATI	ONS					
TEM	ELEMENT DESCRIPTION	CUT- TER	LOC.	APP +OT b	TOT. LOC.	STD. HRS./ INCH d	0CC e	MACH TIME e
	M. The The I Peas	?"			ぶせのいい	. 3.3272	/ 7	, = =
	Pour Mill Pocket 23 Layers x /3 Passe	59"			2.40.70	, 66006	23×13	2.36
	-504 lpm Finish Mill Pocket 1 Pass	9"			240,00	م م	1 × 13	, 2 4.
	216 ipm Mill T-Rib 2 Passes	 -/"			د ز رو کہ جدا	. 222,55	2824	
	108 jpm + TRETA					. 21115		
	108 lam 4 Teeth	\$1 <u>0</u> "						
	108 ipm 4 Teeth	1 3	<u> </u>		6/0,30	. 333 <i>: E</i>	/	: چزر را ا
	Mill Taper on Tee / Pass 30 ipm	211	<u> </u>		13,00	, 332,55	24	, ३ व
	Machining Time/Spindle for 4 Spindle	М		(2)	1	2)	421	
	Milling Time	Mack	<u> </u>		1	1	(5)	5, 5,
	Cutter Repositionina Total Machinina Tin	ا ان (25	X 		1417	3.5
		1		1	<u> </u>	1	1	
<u> </u>	Machining Time / Spindle for 1 or 2 Sp Milling Time Total Machining Time	lind/e	1 Mx	lchir	्रम्ड (°	6001pm)	.34
	Total Machining Time	(hrs	j)		<u> </u>		1	5.90
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	MACHINE RUN CALCU	JLATI	ONS					
ITEM NO.	ELFMENT DESCRIPTION	CUT- TER		APP +OT b	TOT. LOC.	STD. HRS./ INCH d	occ e	MACH TIME e
	Mill Top of Ter / Pass	9"			= 40,33	.000058	12	ذ (،
	Fough Mill Pocket 52 Layers	7"			בנוטניה	.000025	22×13	1.7.
	Finish Mill Pocket 1 Pasa	19"			240,33	 .১৪८२ <i>५</i> ८	12/3	<u> </u>
	Mill T- Rie 3 France	1411	l		دد بن جا	1,20012	2 424	11.5
	Mill Edge of Tee / Pass	5 2				,5:3/A		
1	Mill Periphery 1 Pass	21/2"						
	144 ipm 4 /ecth					.23312		
	Mill Taper on Tee / Pass	3,	<u> </u>		3,20	, 220,55	24	, 5.
							408	
	Milling Time for I Culter Reposition in	02	Spind	/u /	lachin	مي در		4.=
	Total Machini	3 70	.'00135 VP_	Shr			1424	1.7.
	Milling Time for 4 Sp Cuttor Repositioning	Indi	/ 16	hla	. <u> </u>			14,4
	Cuttor Repositioning		. <u>3325</u>		×		227	5.0
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Table 8-8 7" Diameter Cutter, & Teath, 150 HP. 54,000 SEN

ELEMENT DESCRIPTION				1		CTD)		
		CUT-	LOC.	APP +OT b	TOT. LOC. c	STD. HRS./ INCH d	OCC e	MACH. TIME e
Mill Top of Tize	1 Pass	1911			240.00	.000029	12	, 184
576 Ipm Rough Mill Pocket	23 Lavers	911		 	240.00	.000017	23×/3	1,220
Finish Mill Pocket	of mashine)	1						
Finish Mill Pocket	1 Pass	17"	<u> </u>	 	240.00	,000029	/2	1,524
Mill T- Rib	2 Passes	1 1"	<u> </u>		5.13.30	1.03336	48	1.57/
288 ipm								
Mill Edge of Tee	1 Pass	12 /2"	 		=40.33	, 2222 %		1.3.13
Mill Periphery	1 Pass	2/2"		 	613.30	,20026	1	1,037
288 ipm		1						
Mill Taper on Tee	1 Pass	13"	<u> </u>		3.33	1, 20155	24	1 , 3-13
							420	
		1					-4	
Milling Tim	acitionin a	+	1.0005	X		<u> </u>	1316	2.50
Total	Machining Ti	1. 12 Ci		1	i			2.7/0
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NOTE: The crossed out feed	rate was	1		 	<u> </u>			
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	Mill Edge of Tee 288 ipm Mill Periphery 288 ipm Mill Taper on Tee Milling Tim Cutter Rap Total NOTE: The crossed out feed reduced due to the 1, gantry feed limitatio	Mill Edge of Tee Pass 288 ipm Mill Periphery Pass 288 ipm Mill Taper on Tee Pass Cutter Rapositioning Total Machining Tire NOTE: The crossed out feed rate was reduced due to the 1,000 ipm gantry feed limitation.	NOTE: The crossed out feed rate was reduced due to the 1,000 ipm gantry feed limitation.	### Action Page Pag	288 jpm Mill Edge of Tee Pass 2½ 288 jpm Mill Taper on Tee Pass 2½ Milling Time Cutter Repositioning Time (inci) NOTE: The crossed out feed rate was reduced due to the 1,000 jpm gantry feed limitation.	28 jpm Mill Edge of Tee Pass Z'a' Frio.93 28 jpm Mill Periphery Pass Z'a' 619,00 28 jpm Mill Taper on Tee Pass Z'' 3,00 Milling Time Cutter Repositioning Time (inc) Total Machining Time (inc) NOTE: The crossed out feed rate was reduced due to the 1,000 jpm gantry feed limitation.	### All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Pass All Edge of Tee Edg	### ### ##############################

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APPENDIX C

FLOOR-TO-FLOOR MACHINING TIME AND MONTHLY PANEL MACHINING CAPACITY

C-1	One Spindle Machine - One Panel Length Table
C-2	Two Spindle Machine (Machining One Panel) - One Panel Length Table
C-3	Four Spindle Machine (Machining Two Panels) - One Panel Length Table
C-4	One Spindle Machine - Two Panel Length Table
C-5	Two Spindle Machine - Two Panel Length Table
C-6	Four Spindle Machine - Two Panel Length Table

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Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity One Spindle Machine Table C-1.

·							One Panel Length Table	ngth Table	[] VII.
					MAC	MACHINE TOOL C	CONFIGURATIONS	Sk	
** Requires 2 spindles		RETROFI	OFIT				NEW		
	PRESENT 1 Spindle	CONV.	HSM	CONVEN	CONVERTIONAL		HIC	HIGH SPEED MACHINING	HINING
	Existing	Existing	Existing	Horiz. For Rough Vert. for	Vertical	Verring	Loopanon	1.00	
	20 hp 3600 rpm	100 hp	100 hp	Finish 1005150 hp	•	Spindle 75 hp	Spindle 100 hp	Spindle 150 hp	Spindle 150 hp
Cutters→ PARAMETERS		9" Rough	9" Rough	14" Rough	100 4	9" Rough	9" Rough	24000 rpm 9" Rough	24000 rpm 2" Rough
Machining Time	52.468	10.493	5.020	11.367		5.906	4.755	2.710	2.860
(hours) Break, Fatigue and Personal Time (hrs) (20% of Machining	10.494	2.099	1.004	2.273	1.952	1.181	.951	:542	.572
Time) Shop Machining Time (hours)	62.962	12.592	6.024	13.640	11.710	7.087	5.706	3.252	3.432
Panel Loading and Unloading Time (hours)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total Floor-To- Floor Time (hours)	65.962	15.592	9.024	16.640	14.710	10.087	8.706	6.252	6.432
Monthly Panel Capacity/2 Shifts (no. panels)	6.4	19.5	36.1	19.6	22.1	32.3	37.4	52.1	50.6
		-	-	ggarl Rajon	-				Po

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Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity Two Spindle Machine (Machining One Panel) Table C-2.

One Panel Length Table

	MACHINE TOOL CONFIGURATIONS	NEW	CONVENTIONAL HIGH SPEED MACHINING	Vertical Vertical Vertical V	Spindle Spindle Spindle Spindle 150 hp 75 hp 100 hp 150 hp 3600 rpm 9000 rpm 12000 rpm 24000 rpm	9" Rough 9" Rough 9" Rough & Finish & Finish	4.879 2.953 2.378 1.355	.37 .976 .591 .476 .271 .286	21 5.855 3.544 2.854 1.626 1.716	3.0 3.0 3.0 3.0	21 8.855 6.544 5.854 4.626 4.716	36.8 49.7 55.6 70.4 69.0
anel Lengti	MACHINE TOOL			-		+			<u> </u>	3.0	<u> </u>	70.4
one F		NEW		Verrios		9" Roug	2.378	947-	2.854	3.0	5.854	55.6
				Verrical	Spindle 75 hp 9000 rpm	9" Rough	2.953	.591	3.544	3.0	6.544	49.7
			TIONAL					926.	5.855	3.0	8.855	36.8
			CONVE	* Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough , 9" Finish	5.684	1.137	6.821	3.0	9.821	33.1
		RETROFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish	2.510	.502	3.012	3.0	6.012	54.1
			CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish	5.247	1.049	6.296	3.0	9.296	35.0
			PRESENT	Existing	20 hp 3600 rpm	5½" Pough & Finish	(hrs) 52.468 ref.	10.494 ref.	62.962 ref.	3.0 ref.	65.962 ref.	4.9 ref.
		*Requires 4 spindles	7			Cutters+ FARAMETERS	Machining Time (hrs) (inc. cutter Positioning)	Break, Fatigue and Personal Time(hrs) 20% of Machining Time	Shop Machining Time (hours)	Panel Loading and Unloading Time (Hours)	Total Floor-to-Floor Time (Hours)	Monthly Panel Capacity/2 Shifts (No.Panels)

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Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity Four Spindle Machine (Machining Two Panels) Table C-3.

2" Rough 9" Finish 24000 rpm Vertical 150 hp Spindle .715 .143 .858 2.250 3.108 104.7 SPEED MCHINING 24000 rpm Vertical & Finish 9" Rough Spindle 150 hp One Panel Length Table .678 2.250 .136 .814 3.064 106.2 HICH MACHINE TOOL CONFIGURATIONS 12000 rpm 9" Rough & Finish Vertical NEW Spindle 100 hp 1.255 .238 1.493 2.250 3.743 87.0 9000 rpm 9" Rough 6 Finish /ertical 75 hp Spindle 1.651 .295 1.946 2.250 4.196 77.6 Vertical 3600 rpm Spindle 150 hp 9" Rough & Finish 2.478 .496 5.224 2.974 2,250 CONVENTIONAL 62.3 14" Rough 9" Finish Vert. for for Rough 1005150 hp Finish 3600 rpm Horiz. .579 3.476 5.726 2.897 2.250 56.8 100 hp 12000 rpm 9" Rough & Finish Existing HSM ١ L ı RETROFIT 100 hp 3600 rpm Existing 9" Rough & Finish CONV. ١ PRESENT Spindle 20 hp 3600 rpm 5½" Rough Existing & Finish 52.468 10.494 62.962 65.962 3.0 4.9 Cutters→ Machining Time (hrs) fonthly Panel Capacity Total Floor-to-Floor Unloading Time (hrs) 2 Shifts (No.Panels) Shop Machining Time Personal Time (hrs) Break, Fatigue and (20% of Machining Panel Loading and Time (Hours) **PARAMETERS** (Hours) Time)

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Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity (One Spindle Machine) Table C-4.

Table
Length
Panel
Two

-		orang d	# A A A		MACI	MACILINE TOOL C	CONFIGURATIONS	Length	lable
		RETR	RETROFIT				NEW		
	PRESENT	CONV.	HSM	CONVENTIONAL	TONAL.		HIGH	H SPEED MACHINING	HINING
	Existing	Existing	Existing	Horiz. for Rough Vect. for	Vertical	Vertical	Verrical	Vertical	Vertical
	20 hp 3600 rpm	100 hp 3600 rpm	100 hp 12000 rpm	resish 100&150 hp 3600 rpm	Spindle 150 hp 3600 rpm	Spindle 75 hp 9000 rpm	Spindle 100 hp 12000 rpm	Spindle 150 hp 24000 rpm	Spindle 150 hp 24000 rpm
Cutters→ PARAMETERS	5½" Rough & Finish	9" Rough & Finish	9" Rough & Finish	14" Rough 9" Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	2" Rough 9" Finish
G Machining Time (Hrs) (Incl. Cutter Positioning)	52.468	ı	l	11,367	9.758	5.906	4.755	2.710	2.860
Break, Fatigue and Personal Time (Hrs) (20% of Machining Time)	10.494	ı	ı	2.273	1.952	1.181	.951	.542	.572
Shop Machining Time (Hours)	62.962	ı	ı	13.640	11.710	7.087	5.706	3.252	3.432
Additional Panel Loading and Unload- ing Time (Hours)	ı	I	1	0	0	0	•	0	0
Total Floor-to-Floor Time (Hours)	65.962	l	ı	13.640	11.710	7.087	5.706	3.252	3.432
Monthly Panel Capacity/2 Shifts (# panels)	4.9	1	ı	23.9	27.8	45.9	57.0	100.1	94.8
					•	•	•	~	

Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity Two Spindle Machine Table C-5.

			Ę	Vertí	Spind.		OR! OF	GINAL PAG POOR QUA	re is			
Length			HINING (HSM)	Vertical	Spindle 150 hp 24000 rpm	2" Rough 9" Finish	1.430	.286	1.716	1.284	3.000	108.5
Table	NS		H SPEED MACHINING	Vertical	Spindle 150 hp 24000 rpm	9" Rough & Finish	1.355	.271	1.626	1.374	3.000	108.5 (200.2)
Two Panel	CONFIGURATIONS	NEW	нотн	Vertical	Spindle 100 hp 12000 rpm	9" Rough & Finish	2.378	.476	2.854	.146	3.000	108.5 (114.1)
	MACHINE TOOL C			Vertical	Spindle 75 hp 9000 rpm	9" Rough & Finish	2.953	.591	3.544	0	3.544	91.8.
	MACII		TIONAL		Spindle 150 hp 3600 rpm	9" Rough & Finish	4.879	926.	5.855	0	5.855	55.6
			. CONVENTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish	5.684	1.137	6.821	0	6.821	47.7
		OFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish	1	1	f	ı	1	(
		RETROFIT	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish		ı	!	ı	ı	ı
			PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish	52.468	10.494	62.962	1	65.962	4.9
	(XXX) Values not limited by load/ unload times Cutters→				Machining Time (hrs) (incl. cutter Positioning)	Break, Fatigue and Personal Time (Hrs) (20% of Machining Time)	Shop Machining Time (Hours)	Additional Panel Loading and Unload- ing Time (Hours)	Total Floor-to-floor Time (Hours)	Monthly Panel Capacity/2 Shifts (# Panels)		

Total Floor-to-Floor Machining Time and Monthly Panel Machining Capacity Four Spindle Machine Table C-6.

Two Panel Length Table

				<u>. </u>				ORIGINAL OF PO	AL FOR			
			HINING	Vertical	Spindle 150 hp 24000 rpm	2" Rough 9" Finish	.715	.143	. 858	1.594	2.250	144.7
0	VS	n	H SPEED MACHINING	Vertical	Spindle 150 hp 24000 rpm	9" Rough & Finish	.678	.136	.814	1.436	2.250	144.7 (399.9)
	CONFIGURATIONS	NEW	HIGH	Vertical	Spindle 100 hp 12000 rpm	9" Rough & Finish	1.255	.238	1.493	.757	2.250 (1.493)	144.7 (218.0)
İ	MACHINE TOOL C			Vertical	Spindle 75 hp 9000 rpm	9" Rough & Finish	1.651	. 295	1.946	.304	2.250 (1.946)	144.7
	MAC		LIONAL	Vertical	Spindle 150 hp 3600 rpm	9" Rough & Finish	2.478***	.496	2.974	0	2.974	109.4
			CONVENTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish	2.894***	.579	3.476	0	3.476	93.6
		RETROFIT	HSN	Existing	100 հր 12830 rpm	9" Rough & Finish	1	ŧ	ı	ı	1	ı
		RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish	1	l	1	ı	į	ļ
			PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish	52.468	10.494	62.962	ı	65.962	4.9
	(XXX) Values not	limited by load/	unioad time	by gantry feed		Cutters→ PARAMETERS	Machining Time (Hrs) (Incl. Cutter Positioning)	Break, Fatigue and Personal Time (Hrs) (20% of Machining Time)	Shop Machining Time (Hours)	Additional Panel Loading and Unload- ing Time (Hours)	Total Floor-to-Floor Time (Horus)	Monthly Panel Capacity/2 Shifts (# Panels)

APPENDIX D

LABOR COSTS

D-1 Cost per Panel and Per 5,376 Panels - One Panel Length Table

D-2 Labor Cost Per Panel and Per 5,376 Panels -Two Panel Length Tables

Table D-1. Cost (\$): Per Panel and Per 5,376 Panels

				_							Or	PU	UK	QUA	LII T				
			HINING	[0 0 p 4 m 0])	Spindle 150 hp	2" Rough	ustura c	6.432	386	2,075K		912.7		1,521K		3.108	186	1,000K	
able	4S		H SPEED MACHINING	Vortical	Spindle 150 hp 24000 rom	9" Rough	DETHITSH	6.252	375	2,016K		7636	278	1,495K		3.064	184	389K	
One Panel Length Table	MACHINE TOOL CONFIGURATIONS	NEW	HIGH	Verrical	Spindle 100 hp	9" Rough	HCTHIT 4 D	8.706	522	2,806K		5.854	351	1,887К		2.743	225	1,209K	
One Pa	HINE TOOL C			Vertical	Spindle 75 hp 9000 rpm	9" Rough		10.087	605	3,252K		6.544	393	2,113K		4.196	252	1,355K	
	MAC		FIONAL	Vertical	Spindle 150 hp 3600 rpm	5 4		14.710	883	4,474K		8.855	531	2,855K		5.224		1,683K	
			CONVERTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish		16.640	866	5,365K		9.821	589	3,166К		5.726	344	3849K	
		OFIT	HSM	Existing	12000 rpm	9" Rough		9.024	541	2,908K	-	6.012	361	1,941K		1	ı	1	
		RETROFIT	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish		15.592	936	5,031K		9.296	558	3,000K		1	ı	1	
	•		PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish		65.962	3,958	21,278K		ı	ı	ı		ı	,	ı	-
						Cutters→ PARAMETERS	One Spindle	Hours/Panel	\$7Panel	\$/5,376 Panels	Tuo Soindle	Hours/Panel	\$/Panel	\$/5,376 Panels	Four Spindle	Hours/Panel	\$/Panel	\$/5376 Panels	

D-2

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Iwo Panel Length Table

Table D-2. Labor Cost (\$): Per Panel and Per 5,376 Panels

CONVVC. H354						MACHINE	្ឋដ	Two Panel Length Table OL CONFIGURATIONS	h Table NS	
Existing Existing Figure			RETR	OFIT				NEW		
Existing Existing Vert. for Rough 100.150 pp	PRESENT	Į.	CONV.	ИSН	CONVENT	IONAL		HIG		HINING
Name	i d		ŗ	F	Horiz. for Rough		,	,		
100 hp 100 hr 1006,150 hp 150 hp 150 hp 150 hp 150 hp 150 hp 1500 rpm 240000 rpm 240000 rpm 240000 rpm 240000 rpm 240000 rpm 240000 rpm 240000 rpm 24000	בעדפר	7 TE	EXTECTION	gurastxa	Veil. for Finish	Vertical Spindle	Vertical Spindle	Vertical Spindle	Vertical Spindle	Vertical Spindle
9" Rough 9" Rough	20 hp 3600 rpm	np rpm	100 hp 3600 rpm	100 hp 12000 rpm	100&150 hp 3600 rpm	150 hp 3600 rpm	75 hp 9000 rpm	100 hp 12000 rpm	150 hp 24000 rpm	150 hp 24000 rpm
- -	Cutters→ 'k" Rough & Finish	ough Ish	9" Rough & Finish	9" Rough & Finish		9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	9" Rough & Finish	2" Rough 9" Finish
- - 13.640 11.710 7.087 5.706 3.252 3 - - 818 703 425 342 195 1 - - 4,398K 3,779K 2,285K 1,839K 1,046K 1 - - 6,821 5,855 3,544 3,000 3,000 3 - - 409 351 213 180 180 1 - - 409 351 213 180 180 1 - - 409 351 213 180 180 1 - - 409 351 1,145K 968K 968K 968K - - 2,199K 1,887K 1,145K 968K 968K 968K - - - 3,476 2,974 2,250 2,250 2,250 - - - 209 178 135 135 - - - 209 178 2,26K 726K -										
818 703 425 342 195 4,396K 3,779K 2,285K 1,839K 1,046K 1 6,821 5,855 3,544 3,000 3,000 409 351 213 180 180 409 351 213 868K 968K 968K 968K 96	65.962	62	ı	1	13.640	11.710	7.087	5.706	3.252	3.432
4,398K 3,779K 2,285K 1,839K 1,048K 1,048K 1,048K 1,048K 1,048K 1,048K 1,048K 1,048K 1,048K 1,048K 1,049K 1,049K 1,145K 968K 968K 968K 968K 968K 968K 968K 968	3,958	28	ı		818	703	425	342	195	206
- 6,821 5,855 3,544 3,000 3,000 1,00	21,2	78K	ı	1	4,398K	3,779К	2,285K	1,839K	1,048K	1,107K
- 6,821 5,855 3,544 3,000 3,000 1 - 409 351 213 180 180 180 - 409 351 213 180 180 180 - 2,199K 1,887K 1,145K 968K 968K 968K - 3,476 2,974 2,250 2,250 2,250 - 209 178 135 135 135 - 1,124K 957K 726K 726K 726K (6,29K) (4,84K) (2,63K) (6,29K) (4,84K) (2,63K)						<u> </u>				
- 409 351 213 180 (1.626) 1. - 2,199K 1,887K 1,145K 968K 968K 968K 968	ı		t	1	6,821	5,855	3,544	3,000	3,000	3.000
- 409 351 213 180 180 - 2,199K 1,887K 1,145K 968K 968K 968K 968K 957K (919K) (527K) - 3,476 2,974 2,250 2,250 2,250 2,250								(2.854)	(1.626)	1.716)
- 2,199K 1,887K 1,145K 968K 968K 968K 968K 968K 968K 968K 968	1		1	ı	409	351	213	180	180	180
- 2,199K 1,887K 1,145K 968K 968K 968K								(171)	(86)	(103)
- 3,476 2,974 2.250 2.250 2.250 2 - 209 178 135 135 135 - 1.124K 957K 726K 726K 726K . (629K) (484K) (263K)	1		ı	ı	2,199K	1,887K	1,145K	968К	368К	968К
- 3,476 2,974 2,250 2,250 2,250 2 (1,946) (1,493) (.814) (- 209 178 135 135 135 - 1,124K 957K 726K 726K 726K (629K) (484K) (263K)								(919K)	(527K)	(554K)
- 3,476 2,974 2.250 2.250 2.250 2 (1.946) (1.493) (.814) (- 209 178 135 135 135 135 (117) (90) (49) (49) (49) (49) (49) (49) (49) (49										
- 209 178 135 135 135 135 - 13	1		ı	i	3,476	2,974	2.250	2.250	2.250	2.250
- 209 178 135 135 135							(1.946)	(1.493)	(.814)	(.858)
- 1.124K 957K 726K 726K 726K 726K 726K (484K) (263K)	t		ı	ı	. 209	178	135	135	135	135
- 1.124K 957K 726K 726K 726K (629K) (484K) (263K)							(117)	(06)	(64)	(51)
(484K) (263K)	1		1	•	1.124K	957K	726К	726K	726K	726K
						······································	(629K)	(484K)	(263K)	(274K)

APPENDIX E

MACHINE INVESTMENT COST

E-1	One Spindle (One Panel Width) -
	One Panel Length Table
E-2	Two Spindle (One Panel Width) -
	One Panel Length Table
E-3	Four Spindle (Two Panel Width) -
	One Panel Length Table
E-4	One Spindle (One Panel Width) -
	Two Panel Length Table
E-5	Two Spindle (One Panel Width) -
	Two Panel Length Table
E-6	Four Spindle (Two Panel Width) -
	Two Panel Length Table

Table E-1. Machine Investment Cost (\$) per Panel and Per 5,376 Panels One Spindle (One Panel Width)

*

							. ORIGIÑ	IAL	PAGI					
			HINING	Vertical	Spindle 150 hp 24000 rom	2" Rough 9" Finish	1,400K	ı	ı	72.5K	12K	1,484.5K	276	
able	Sk		H SPEED MACHINING	Vertical	Spindle 150 hp 24000 rpm	9" Rough & Finish	1,400K	i	l	72.5K	12K	1,484.5K	276	
One Panel Length Table	CONFIGURATIONS	NEW	нісн	Vertical	Spindle .100 hp 12000 rpm	9" Rough & Finish	1,500K	ţ	225K	72.5K	12K	1,809.5K	337	
One Par	NACHINE TOOL C			Vertical	Spindle 75 hp 9000 rpm	9" Rough & Finish	1,400K	ı	225K	72.5K	12K	1,709.5K	318	
	MAC		FIONAL	Vertical	Spindle 150 hp 3600 rpm	9" Rough & Finish	1,750K	ı	225K	72.5K	12K	2,059.5K	383	
			CONVENTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish	1,900K	ı	225K	72.5K	12K	2,209.5K	411	
		RETROFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish	0	235K	1.	5K	2K	242K	45	
		RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish	o	50K	1	1K	ı	51K	ი	
			PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish	c	ı	1	ł	ı	ı	0	
						Cutters*	Cost of Machine (FOB Huntsville)	Cost of Additions	Vacuum Chuck (if separate)	<pre>Installation (Incl. Foundation)</pre>	Debug and Test	Total Additional Machine Cost	Total Additional Machine Cost/Panel (Based on 5,376 Panels)	

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Machine Investment Cost (\$) per Panel and per 5,376 Panels Two Spindle (One Panel Width) Table E-2.

One Panel Length Table	MACHINE TOOL CONFIGURATIONS	NEW	CONVENTIONAL HIGH SPEED MACHINING	Horiz. for Rough	Vertical Vertical Vertical	100£150 hp 150 hp 75 hp 100 hp 150 hp 150 hp 3600 rpm 3600 rpm 260000 rpm 260000 rpm 26000 rpm 2	h 9" Rough 9" Rough 9" Rough 6 Finish & Finish	C DISTUIT B DISTUIT B DISTUIT B	2,200K 1,900K 1,550K 1,850K 1,650K 1,650K		225°C 225K 225K	73K 73K 73K 73K 73K	13K 13K 13K 13K 13K	2,511K 2.211K 1.861K 2.161K 1.736K 1.736K	467 411 346 402 323 323	
<i>t</i> 1		RETROFIT	CONV. HSM		Existing Existing	100 hp 100 hp 3600 rpm 12000 rpm			0	100К 400К	l I	1.5К 7.5К	- 3K	101.5K 410.5K	19 76	
			Ĺ	37	Existing Exi	20 hp 10 3600 rpm 360	54" Rough 9" & Finish & F		0	,	1	ı	•	- 10	0	<u> </u>
L			•				Cutters→ PARAMETERS		Cost of Machine	Cost of Additions	Vacuum Chuck (If Separate)	Installation (incl. Foundation)	Debug and Test	Total Additional Machine Cost	Total Additional Machine Cost/Panel (Based on 5,376 Panels)	

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Machies Investment Cost (\$) per Panel and per 5,376 Panels Four Spindle (Two Panel Width) Table E-3.

				Γ	,	ᅼ	B	T4 48	Π					<u> </u>	<u>.</u>	1			 	
			DATATA	TILLIN LING		Vertical Spindle	24000 rpm	2" Rough 9" Finish		2,500K		1 1	82 58	70	16.5K	2,599K	•	483		
gth Table	SNS		HIGH SPEEN MACHINING		,	Spindle 150 hp	24000 rpm	9" Rough & Finish		2,500K		1 1	82.5K		16.5K	2,599K		493		
One Panel Length Table	MACHINE TOOL CONFIGURATIONS	NEW	IH		Verrical	Spindle 100 hp	12000 rpm	9" Rough & Finish		2,500K		- 400K	82.5K	! !	16.5K	2,999K	o v	900		
Or	CHINE TOOL				Vertical	Spindle 75 hp	9000 rpm	9" Rough & Finish		2,400K		- 400K	82.5K	,	10.5K	2,899K	539			
	MAC		CONVERTIONAL	,	Vertical	<u> </u>	3600 rpm	9" Rough & Finish		2,400K	•	400K	82.5K	16 SV	4C - OT	2,899K	539			-
			CONVE	Horiz	for Rough Vert. for	Finish 100&150 hp	3600 rpm	14" Rough 9" Finish		3,100K	ı	400K	82.5K	16.5K	40.	3,599К	699			
	}	7																	 	
		KETROFIT	HSM		Existing	100 hр	mdi nonzi	9" Rough & Finish		ı	ı	ı	ı	ı		ı	ı			
		KET	CONV.		Existing	100 hp	ind 1 poper	y Kough & Finish		1	1	1	1	ı		1	ı			
		Service of the servic	PRESENT L Spindle		Existing	20 hp 3600 rom				ı	1	ı	ſ	1		ı	ı	(s)		
-							(inflore-	PARAMETERS	3	Cost of Machine (FOB Huntsville)	Cost of Additions	Vacuum Chuck (If Separate)	Installation (incl. Foundation)	Degub and Test		Total Machine Cost	Total Machine Cost/	(based on 5,376 pane		

Machine Investment Cost (\$) per Panel and per 5,376 Panels One Spindle (One Panel Width) Table E-4.

	_		_	_					-			ORK OF 1	einal 'Oor -	OUAL	3 69 Live				
			HTWING		:	Vertical Spindle	150 hp	2" Rough	9" Finish	1,550K		1 1	82.5K	12K		1,644.5K	306		
h Table	SN		CH SPEED MACHINING			Vertical Spindle	150 hp 24000 rpm	9" Rough	6 Finish	1,550K		1 1	82.5K	12K		1,644.5K	306		
Two Panel Length Table	CONFIGURATIONS	NEW	HIGH		P	Spindle	100 hp 12000 rpm	9" Rough	a Finish	T. O SUK		- 400K	82.5K	12K		2,144.5K	399		
Two	MACHINE TOOL				Verrical	Spindle	75 hp 9000 rpm	9" Rough	1 5500	Vocc 17	ļ	400K	82.5K	12K		2,044.5K	380		
	MAC		CONVENTIONAL.		Verrical		150 hp 3600 rpm	9" Rough		1000 t	1	400K	82.5K	12K		2,494.5K	797		
			CONVER	Horiz.	for Rough Vert. for	Finish	3600 rpm	14" Rough 9" Finish	2.150K		ţ	400K	82.5K	12K		2,644.5K	492		
		RETROFIT	HSM		Existing	100	12000 rpm	9" Rough & Finish			ı	ı	1	1		ı	ı		,
		RETR	CONV.		Existing	100 hn	3600 rpm	9" Rough & Finish			ı	ı	ı	ı		1	l		
			PRESENT		Existing	20 hp	3600 грш	Cutters 54" Rough	ı		ı	ı	ı	ſ			ı	-	-
**							er Vendus	Cutters	Cost of Machine	(FOB Huntsville)	Cost of Additions	Vacuum Chuck (1f separate)	Installation (Incl. Foundation)	Debug and Test	Total Machine Cost	1800 20000000000000000000000000000000000	Total Machine Cost/ Panel (Based on 5,376 Panels)		

Machine Investment Cost (\$) per Panel and per 5,376 Panels Two Spindle (One Panel Width) Table E-5.

							OF	P00	K	QUAL	31 1				
			HINING	Vertical Spindle	150 hp 24000 rpm	2" Rough 9" Finish	1,800K		ļ	ı	85K	13K	1 898%	353	
Two Panel Length Table	St		HIGH SPEED MACHINING	Vertical Spindle	150 hp 24000 rpm	9" Rough 6 Finish	1,800K		ī	ı	85K	13K	1,898K	353	
Two Panel L	CONFIGURATIONS	NEW	HIG	Vertical Spindle	100 hp 12000 rpm	9" Rough & Finish	2,000K		ı	400K	85K	13K	2,498K	465	
	MACHINE TOOL CO			Vertical Spindle	75 hp 9000 rpm	9" Rough & Finish	1,700К		ı	400K	85K	13K	2,198K	607	
	MAC		FIONAL	Vertical Spindle	150 hp 3600 rpm	9" Rough & Finish	2,150K		1	400K	85K	13K	2,648K	493	
			CONVERTIONAL	Horiz. for Rough Vert. for Finish	100&150 hp 3600 rpm	14" Rough 9" Rough 9" Finish & Finish	2,450K	•	ı	400K	85K	13K	2,948K	248	
	=	RETROFIT	HSH	Existing	100 Mp 12000 rpm	9" Rough & Finish	•		1	•	ſ	ı	ı	•	
		RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish	1		ı	1	ı		ı	1	
			PRESENT	Existing	20 hp 3600 rpm	Cutters+ 5½" Rough & Finish			ı	ı	ı	ı	l	I	
; 						PARAMETERS	Cost of Machine (FOB Huntsville)		Cost of Additions	Vacuum Chuck (If Separate)	Installation (incl. Foundation)	Debug and Test	Total Machine Cost	Total Machine Cost/ Panel	(based on 5,376 panels)

Machine Investment Cost (\$) per Panel and per 5,376 Panels Four Spindle (Two Panel Width) Table E-6.

							ORIG	NA OO	L PAG	SE IS				
			HINING	Vertical Spindle	24000 rpm	2" Rough 9" Finish	2,800K	J	ı	. ж	16.5K	2,906.5K	541	
gth Table	S		H SPEED MACHINING	Vertical Spindle	24000 rpm	9" Rough & Finish	2,800K	ı	ı	90K	16.5K	2,906.5K	541	
Two Panel Length Table	CONFIGURATIONS	NEW	нлен	Vertical Spindie 100 hn	12000 rpm	9" Rough & Finish	2,800K	ı	700K	90K	16.5K	3,606.5K	671	
T	MACHINE TOOL C			Vertical Spindle 75 hp	9000 rpm	9" Rough & Finish	2,700K	1	700K	90K	16.5K	.3,506.5K	652	
	MAC		TIONAL	Vertical Spindle 150 hp	_	9" Rough & Finish	2,700K	ı	700K	90K	16.5K	3,506.5K	652	
			CONVENTIONAL	Horiz. for Rough Vert. for Finish 100&150 hp	3600 rpm	14" Rough 9" Finish	3,400K	ı	700K	90K	16.5K	4,296.5K	782	
				80 G	Ē.	e								
		RETROFIT	HSM			9" Rough & Finish	ı	ı	ı	ı	1	ı	ı	
		RETR	CONV.	Existing 100 hp	3600 rpm	y Kough & Finish	1	ı	ı	1	ı	1	ļ	
	į		PRESENT	Existing 20 hp		& Finish	ı	1	ı	ı	ŧ	ı	ı	
						PARAMETERS	Cost of Machine (FOB Huntsville)	Cost of Additions	Vacuum Chuck (if separate)	Installation (inc. Foundation)	Debug and Test	Total Machine Cost	Total Machine Cost/ Panel (Based on 5,376 Panels)	

APPENDIX F

MACHINE INVESTMENT PLUS LABOR COSTS

F-1	0ne	Pane1	Length	Tab1e	-	0ne	Spindle
F-2	One	Pane1	Length	Table	-	Two	Spindles
F-3	One	Pane1	Length	Table	-	Four	Spindles
F-4	Two	Panel	Length	Table	-	One	Spindle
F-5	Two	Pane1	Length	Table	-	Two	Spindles
F-6	Two	Panel	Length	Table	_	Four	Spindles

Table F-1. Combined Machine Investment Plus Labor per Panel and per 5,376 Panels (\$)

	_		· ************************************		·							 	
One Spindle		HINING	Vertical Spindle 150 hp	24000 rpm 2" Rough 9" Finish		276	386	662	1,485K	2,075K	3,560K		
1	>	H SPEED MACHINING		24000 rpm 9" Rough & Finish		276	375	651	1,485K	2,016K	3,501K		
One Panel Length Table	NEW	HIGH	Vertical Spindle :100 hp	9" Rough & Finish		337	522	859	1,810K	2,806к	4,616K		
One I			Vertical Spindle 75 hp	9" Rough		318	909	923	1,710К	3,252K	4,962K		
MACI		TIONAL	Vertical Spindle 150 hp 3600 rpm	9 0		383	883	1,266	2,060к	4,747K	6,807K		
		CONVERTIONAL	Horiz. for Rouph Vert. for Finish 100&150 hp 3600 rpm	14" Rough 9" Finish		411	866	1,409	2,210K	5, 65K	7,575K		
	RETROFIT	HSM	Existing 100 hp 12000 rpm	9" Rough & Finish		45	541	586	242K	2,908K	3,150K		
	RETR	CONV.	Existing 100 hp 3600 rpm	+		6	936	945	51K	5,031K	5,082K		
		PRESENT	Existing 20 hp 3600 rpm	5½" Rough & Finish		0	3,958	3,958	0	21,278К	21,278K		
				Cutters	One Spindle	Machine Cost/Panel	Labor Cost/Panel	Total Cost/Panel	Machine Cost/5,376 Panels	Labor Cost/5,376 Panels	Total Cost/5,376 Panels		

Table F-2. Combined Machine Investment Plus Labor Cost (\$) Per Fanel and Per 5,376 Panels

L							One Panel Length	gth Table –	Two Spindles
		RETROFIT	OFTT		MACHINE	100L	CONFIGURATIONS	NS	
E E	PRESENT	CONV.	HSM	CONVENTIONAL	TONAL		HIGH	H SPEED MACHINING	IINING
ΕX	Existing	Existing	Existing	Horiz. for Rough Vert. for	Vertical	Vertical	Vertical	Vertical	Vertical
362	20 hp 3600 rpm	190 hp 3600 rpm	100 hp 12000 rpm	100&150 hp 3600 rpm	Spinale 150 hp 3600 rpm	Spindle 75 hp 9000 rpm	Spindle 100 hp	Spindle 150 hp 24000 rpm	Spindle 150 hp 24000 rpm
217.3	5½" Rough & Finish	9" Rough & Finish	9" Rough & Finish	14" Rough 9" Finish	9" Rough & Finish	9" Rœugh & Finish	9" Rough & Finish	9" Rough & Finish	2" Rough 9" Finish
	ı	19	9/	795	411	346	402	323-	323
	1	558	361	589	531	393	351	278	283
	ı	577	437	1,056	942	739	753	879	909
	1	102K	411K	2,511K	2,211K	1,86īK	2,161K	1,736К	1,736К
	ı	3,000K	1,941K	3,166К	2,855K	2,113K	1,887K	1,495K	1,521K
	ı	3,102К	2,352K	5,677K	5,066K	3,974K	4,048K	3,231K	3,257K
	- 7,0 - 21,								
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	-	1 000	ner.		-		Name:		

Table F-3. Combined Machine Investment Plus Labor Cost (\$)
Per Panel and Per 5,376 Panels

	T	T							1				
Four Spindles		MACHINING		Spindle 150 hp	2" Rough 9" Firish		£87	186	699	2,559K	1,000K	3,599K	
1	·	SPEED		Spindle 150 hp	9" Rough		483	184	299	2,599K	989K	3,588K	
TOOL CONFIGURATIONS	NEW	HIGH	Verrical	Spindle 100 hp	9" Rough		558	225	783	2,999K	1,209К	4,208K	
MACILINE TOOL C			Vertical	Spindle 75 hp	9" Rough		539	252	791	2,899К	1,355K	4,254K	
MAC		TIONAL	Vertical	Spindle 150 hp 3600 rem	0 0		539	313	852	2,899K	1,683K	4,582K	
		CONVENTIONAL	Horiz. for Rough Vert. for	Finish 100&150 hp 3600 rpm	14" Rough 9" Finish		699	344	1,013	3,599K	1,849K	5,448K	
	RETROFIT	HSM	Existing	100 hp 12000 rpm	9" Rough & Finish		ì	ı	ı	l	1	ı	
	RETR	CONV.	Existing	100 hp 3600 rpm	9" Rough & Finish		1	ı	ı	. (ı	ı	
		PRESENT	Existing	20 hp 3600 rpm	5½" Rough & Finish		6	1	ı	1	ı	ı	.
•	•.				Cutters→ PARAMETERS	Four Spindle	Machine Cost/Panel	Labor Cost/Panel	Total Cost/Panel	Machine Cost/5,376 Panels	Labor Cost/5,376 Panels	Total Cost/5,376 Panels	

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Table F-4. Combined Machine Investment Plus Labor Cost (\$)
Per Panel and Per 5,376 Panels

	_	_	_	4.4		The state of						w				
Spindle			HINING	Vertical Spindle 150 hp	24000 rpm 2" Rough	7 FINIBN		306	206	512	1,645K	1,107K	2,752K			
Table - One	NS		H SPEED MACHINING	Vertical Spindle 150 hp	24000 rpm 9" Rough	lictura n		306	195	501	1,645K	1,048K	2,693K			
Two Panel Length Table	CONFIGURATIONS	NEW	HIGH	Vertical Spindle 100 hp	9" Rough			399	342	741	2,145K	1,839K	3,984K			
Two Pa	NACHINE TOOL C			Vertical Spindle 75 hp	9" Rough			380	425	1,972	2,045K	2,285K	4,330K			-
	MAC		CONVENTIONAL	Vertical Spindle 150 hp	5 6			797	703	1,167	2,495K	3,779K	6,274K			10 - 10 - 10 - 10 - 10 - 10 - 10 - 10 -
			CONVE	Horiz. for Rough Vert. for Finish 100&150 hp	14" Rough 9" Finish			492	818	1,310	2,645K	4,398K	7,043K			
		RETROFIT	HSM	Existing 100 hp 12000 rpm	9" Rough & Finish			ı	ı	1	ı	1	ı			
		RETR	CONV.	Existing 100 hp 3600 rpm	9" Rough & Finish			ı	ı	1	ı	1	ı		٠	
			PRESENT	Existing 20 hp 3600 rpm	5½" Rough & Finish			ı	ı	ı	I	l .	1	. ,		pre
•					Cutters→ PARAMETERS		One Spindle	Machine Cost/Panel	Labor Cost/Panel	Total Cost/Panel	Machine Cost/5,376 Panels	Labor Cost/5,376 Panels	Total Cost/5,376 Panels			~

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Table F-5. Combined Machine Investment Plus Labor Cost (\$) Per Panel and Per 5,376 Panels

_			Ur			ALII														-
	HINING		Vertical Spindle	150 hp 24000 rpm	2" Rough 9" Finish		353	180	(103)	533	(426)	1,898K	968K	(554K)		2,866K	(2,452K)			
			Vertical Spindle	150 hp 24000 rpm	9" Rough & Finish		353	180	(86)	533	(451)	1,898K	Ж896	(527K)		2,866K	(2,425K)			
NEW	HIG		Vertical Spindle	100 hp 12000 rpm	9" Rough & Finish		595	180	(171)	645	(969)	2,498K	968K	(919K)		3,466K	(3,417K)			
		,	Vertical Spindle	75 hp 9000 rpm	9" Rough & Finish		409	213		622		2,198K	1.145K	•		3,343K				
	TIONAL		Vertical Spindle	150 hp 3600 rpm	9" Rough & Finish		493	351		844		2,648K	1.887K	•		4,535K				
	CONVERT	Horiz. for Rough	Vert. for Finish	100&150 hp 3600 rpm	14" Rough 9" Finish		548	604		957		2,948K	2,199K	•		5,147K				
-				-																
OFIT	HSM		Existing	100 hp 12000 rpm	9" Rough & Finish		1	i		ı		ı	1			ı				
RETR	CONV.		Existing	100 hp 3600 rpm	9" Rough & Finish		ı	1		1		1	ı			ı				
	PRESENT		Existing	20 hp 3600 rpm	5½" Rough & Finish		1	ı		ı		ı	ı			ı	-			r 13
(XXX) Values not	unload times				Cutters→ PARAMETERS	Two Spindle	Machine Cost/Panel	Labor Cost/Panel		Total Cost/Panel		Machine Cost/5,376	Panels Labor Cost/5.376	Panels		Total Cost/5,376	Pariels			
	RETROFIT	not oad/ PRESENT CCNV.	not RETROFIT CONVENTIONAL HIGH SPEED MACH HORIZ.	not PRESENT CCNV. HSM CONVENTIONAL HIGH SPEED MACH For Rough Existing Existing Existing Finish Spindle Spindle Spindle Spindle	not oad/ oad/ PRESENT CONV. HSM CONVENTIONAL HIGH SPEED MACHINING Existing Stirling 20 hp 3600 rpm Existing 100 hp 3600 rpm Existing 12000 rpm Horiz. Finish 3600 rpm Vertical Spindle 5pi	PRESENT CONV. HSM CONVENTIONAL HSM CONVENTIONAL HSM CONVENTIONAL HSM CONVENTIONAL HSM Horiz. Horiz. Finish Spindle	PRESENT CONV. HSN	This continues not PRESENT CONV. HSM CONVEXTIONAL HIGH SPEED MACHINING Horiz.	(XXX) Values not Infinited by load/ unload times PRESENT CONVENTIONAL ACONVENTIONAL HIGH STEED MACHINING unload times PRESENT CONV. HSN CONVENTIONAL HIGH SPEED MACHINING unload times Existing Existing Firsting For Rough Spindle Spind	Thin ted by load PRESENT CONV. HSM CONVERTIONAL For Rough PRESENT CONV. HSM CONVERTIONAL For Rough PRESENT CONV. HSM CONVERTIONAL For Rough Pertical Pertaca Pertical Per	This continue of times RESENT CONV. HSM CONVERTIONAL Horiza Horiza Horiza Horiza Finish Spindle Spindl	Total Cost/Panel PRESENT CONV. HSN CONVERTIONAL HSN Horiz. Finish		Total Cost/5.376 PRESENT CONV. HSM CONVERTITONAL HOTIZ. HOTIZ	Table Cost/Panel Existing	Table December D	Interest of the parameter Existing Exi	Image Preserve Reference	Table Parish Pa	Table Parish Pa

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- Four Spindles			(HSM)	(10)	Spindle	24000 rpm	2" Rough 9" Finish		-			i 9/9	(592)	2,90/K	726K	(274K)	3,633K	(3,181K)				
	2		SPEED MACHINING (H	Vortion	Spindle	24000 rpm	9" Rough & Finish	,	24T	135	(64)	929	(290)	 2,907K	726K	(263K)	3,633K	(3,170K)	•			
Two Panel Length Table	WE TOOKAT TOO	NEW	HIGH SPEED M	Vortical	Spindle	12000 rpm	9" Rough & Finish	į	170	135	(06)	806	(761)	3,607K	726K	(484K)	4,333K	(4,091K)				
Two I	1001			Vortical	Spindle 75 hp	9000 rpm	9" Rough & Finish	61,	052	135	(117)	787	(697)	3,507K	726К	(629K)	4,233K	(4,136K)				
MACI	TOWN:		TONAL	Vortical	Spindle 150 hp	3600 rpm	9" Rough & Finish	C L	259	178		830		3,507K	957K		4,464K		٠			
			NOO	Horiz. for Rough Vert for	Finish 100&150 hp	3600 rpm	14" Rough 9" Finish	000	787	209		991		4,207K	1,124K		5,331K					
Ą	r	寸				Ē								 		_					 	
			HSM	Existing	100 hp	12000 rpm	' Rough Finish		1	1		į		t	ı		ı					
	İ	PEIT	ı	Exi	10	1200	9" & F			•		•										
		RETROFIT	CONV.	Existing Exi		O rpm	9" Rough 9" & Finish & F		ı	1		ı		l	1		I					-
			-		100 hp	3600 rpm	Rough 9' inish &			· · · · · · · · · · · · · · · · · · ·				1	1		1					
			PRESENT CONV.	Existing	100 hp	3600 rpm	9" Rough 9' & Finish &		- Ia	1		ı			st/5,376 -					H(